Radiographic Techniques and Interpretation of the Acute Abdomen

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Radiography is a familiar and available imaging modality for the evaluation of patients with acute abdominal distress. Potential causes for acute abdominal distress include the hepatobiliary system, spleen, urogenital tract, and gastrointestinal tract. Radiographic signs associated with specific conditions are described, including gastric-dilation volvulus, urinary bladder rupture, ureteral rupture, urethral rupture, pancreatitis, and small intestinal obstruction. Additionally, contrast procedures that can be beneficial in evaluating the patient with acute abdomen, including positive contrast cystography, urethrography, excretory urography, and peritoneography, are described.

Abdominal radiography is a widely used diagnostic tool for evaluation of a patient with acute abdominal distress and abdominal pain. Differential diagnoses for animals with acute abdominal distress are numerous, and are reviewed in detail elsewhere.1,2 While the value of radiography for the diagnosis of some acute abdominal disorders (ie, gastric dilation-volvulus (GDV)) is well known, radiography is also very useful for investigating the presence of subtle abnormalities.

With few exceptions, two orthogonal radiographic views of the abdomen should be obtained. One exception is an animal with a suspected trauma, particularly trauma of the spinal cord, in which a lateral radiograph should be viewed before further manipulation of the patient is performed. Evaluation of abdominal radiographs should be completed with a systematic approach and the identification of basic Roentgen signs (changes in size, shape or margination, opacity, number, location, function). An in-depth description of a systematic approach to the abdomen is described elsewhere.3 Contrast procedures may also be beneficial in the evaluation of acute abdominal disorders. When preparing the patient for a contrast procedure, the patient's clinical status and the purpose of the procedure should always be considered.

Extra-abdominal Structures

Evaluation of the caudal thorax and extra-abdominal structures may add valuable information regarding the cause of abdominal abnormalities. For example, the lumbar vertebrae should be evaluated for evidence of lysis or bony proliferation. Discospondylitis results in lysis of adjacent vertebral end plates and adjacent sclerosis.4 Discospondylitis is more common in dogs than cats, with young to middle-aged, large breed dogs being commonly affected. Vertebral body lysis or bony proliferation without involvement of the intervertebral disc space is more suggestive of neoplasia. Metastatic neoplasia more commonly involves the lumbar spine than primary neoplasia. One or more vertebral bodies may be involved with metastatic carcinomas, including prostatic carcinoma, mammary carcinoma, and transitional cell carcinoma.4 Multiple myeloma and hemangiosarcoma can also cause multifocal areas of vertebral lysis.4 In cases of vehicular trauma, the caudal thoracic ribs, lumbar vertebra, and pelvis should be evaluated for fractures. If neurologic deficits, such as fecal or urinary incontinence or paralysis of the tail, are identified, additional radiographs of the pelvis are indicated to further evaluate for caudal lumbar or sacral fractures (Fig 1).

In addition to evaluation of the skeleton, the caudal thorax should be assessed for potential pulmonary metastasis, cardiac abnormalities, lung contusions, and pleural effusion. Additionally, gas dilation of the thoracic esophagus should alert the clinician to investigate the possibility of a megaesophagus, keeping in mind the fact that sedation or anesthesia can also result in gas dilation of the esophagus.

Diaphragmatic Hernia

A diaphragmatic hernia may cause displacement of the liver and omentum into the thorax, resulting in cranial displacement of the stomach. Absence of a liver shadow is suggestive of a diaphragmatic hernia, but displacement of the liver into the thorax may be difficult to visualize because of concurrent pleural effusion and loss of the diaphragmatic outline.5 Additionally, visualization of a tubular gas pattern within a segment of bowel within the thoracic aids in making the diagnosis of a diaphragmatic hernia; however, this is not always present. In questionable cases, positive contrast peritoneography can be performed to confirm the presence of a diaphragmatic hernia. To perform positive contrast peritoneography, the patient should be placed in left lateral recumbency under sedation or general anesthesia.5,6 Following survey radiographs of the abdomen, 0.1 to 0.25 mL/kg of nonionic, iodinated contrast medium with an equal volume of sterile saline is injected into the peritoneal cavity caudolateral and to the right of the umbilicus.6 Aspiration before injecting contrast medium is recommended to rule out inadvertent vascular or intestinal puncture. Warming the contrast medium has also been recommended.5 Following injection of contrast medium, the patient is rotated or the pelvis is raised to allow distribution of the contrast medium. Left lateral, right lateral, ventrodorsal, and dorsoventral radiographs are then obtained. Contraindications to performing peritoneography include hypovolemia, peritonitis, and animals with a known hypersensitivity to contrast media.5 The presence of

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Fig 1. Lateral radiograph of the caudal abdomen of a 3-year old German Shepherd dog with a history of vehicular trauma and questionable urinary incontinence. Note the caudal displacement of the caudal vertebrae relative to the sacrum (arrow). Craniodorsal luxation of a coxofemoral joint is also noted.

contrast medium within the pleural or pericardial space confirms the presence of a diaphragmatic hernia; however, this technique is only 50% sensitive. Pleural or pericardial contrast medium was observed in only 6 of 12 patients confirmed to have diaphragmatic hernias at surgery.5 Stickle reported that the most consistent radiographic finding in animals with diaphragmatic hernia was loss of normal outline of the liver.5 A less common finding was absence of a normal liver shadow.5

Retroperitoneal Space
The kidneys and ureters are normally located within the retroperitoneal space. The kidneys are usually well visualized because of the presence of large amounts of adipose tissue; however, the ureters are too small to be visualized. In a study of 10 cases with ureteral rupture, the most common radiographic finding was loss of detail in the retroperitoneal and peritoneal space (Fig 2).7 However, loss of peritoneal and retroperitoneal detail can occur either separately or concurrently. Although ureteral calculi are rare, the retroperitoneal space should also be evaluated for mineral opacities.8

Excretory urography can be beneficial in evaluating the patency of a ureter.9 The procedure is also recommended for further evaluation of animals with suspected ureteral trauma. In all 10 cases of ureteral rupture reported by Weisse, excretory urography demonstrated leakage of contrast medium from the ureter, whereas retrograde urethrography did not reveal any abnormalities.7

Although ultrasound is commonly used to evaluate the kidneys, excretory urography can be useful in evaluating the kidneys for suspected pyelonephritis and hydronephrosis. In fact, excretory urography is considered superior to ultrasonography for the evaluation of subtle renal pelvic abnormalities.9 Radiographic signs of pyelonephritis include an enlarged, irregular renal pelvis with enlargement or normal size ureter.10 Additionally, multifocal, nonuniform opacification in the nephrogram phase of the excretory urogram can be seen in acute pyelonephritis.11 Before performing excretory urography, survey radiographs should be made for comparison to evaluate for subtle lesions with minimal leakage of contrast medium.10 Additionally, survey radiographs ensure proper radiographic technique and patient preparation. Under ideal circumstances, warm water enemas should be performed the evening before and at least 2 hours before performing the procedure. Venous catheterization is necessary for the administration of contrast medium as
well as for venous access, in case the animal has an adverse reaction to the contrast medium. Sedation is recommended. The dosage of nonionic water-soluble, iodinated contrast medium is 400 mg iodine/lb of body weight given intravenously as a bolus. Although ionic water-soluble, iodinated contrast media have been previously used for excretory urography, the use of nonionic water-soluble, iodinated contrast media has been recommended in high risk patients. Nonionic water-soluble, iodinated contrast media have been used for cystography, urography, angiography, and gastrointestinal studies. Although nonionic water-soluble, iodinated contrast media are more expensive, they have the benefit of fewer adverse side effects. However, its use may be cost prohibitive in large breed dogs if large volumes are needed, such as for cystography. When performing the procedure a ventrodorsal radiograph should be made immediately following injection. Additional lateral and ventrodorsal radiographs should be made 5, 20, and 40 minutes following injection of contrast medium. Oblique radiographs of the caudal abdomen made between 3 and 5 minutes are useful for evaluation of the terminal ureters. A contraindication for performing excretory urography is dehydration. Potential adverse reactions include hypovolemia, cardiac arrest, and acute renal failure. More in-depth descriptions of the technique and assessment of excretory urography are described elsewhere.

**Urinary Bladder**

The most common traumatic urinary tract injury in dogs and cats is rupture of the urinary bladder. Male dogs are at increased risk of traumatic bladder rupture because the male urethra is able to withstand elevated intravesicular pressure encountered with blunt abdominal trauma. There is no sex predilection for urinary bladder rupture in cats. In addition to traumatic urinary bladder rupture, differential diagnoses for uropertoneum include bladder rupture from transitional cell carcinoma or urethral calculi. Radiographically, when the urinary bladder is ruptured, the bladder shadow may not be visible and there may be evidence of peritoneal effusion (Fig 3). In contrast, the presence of a visible urinary bladder shadow does not preclude the presence of a urinary bladder rupture. Pelvic fractures are often identified in animals with urinary bladder ruptures; however, dogs are more likely than cats to suffer urinary tract injuries with pelvic fractures.

Positive contrast cystography is the recommended procedure for the evaluation of urinary bladder rupture. Lateral and ventrodorsal survey radiographs of the abdomen should be obtained. With urinary bladder ruptures in critical cases, fasting and enemas may not be practical nor necessary. However, other potential urinary bladder abnormalities may be missed. Sedation is also advised to aid in catheterization, positioning, avoidance of struggling, and prevention of contrast expulsion from the bladder. The urethra should be catheterized aseptically, and the residual urine in the urinary bladder removed. The urinary bladder is then infused with a 20% solution of water-soluble ionic or nonionic, iodinated contrast medium such as iohexol. The estimated dose of contrast medium is 10 ml/kg of body weight. The bladder is distended with contrast medium until mild resistance is felt on the syringe plunger, or until the urinary bladder feels palpably distended. Further distension of the urinary bladder may result in the accumulation of contrast medium intramurally or subserosally, which may complicate interpretation. Additionally, subtle mucosal or bladder wall abnormalities may be masked. Lateral and ventrodorsal radiographs of the caudal abdomen are then repeated.

Urinary bladder rupture results in leakage of contrast medium at the site of rupture. The contrast medium may be dispersed into the peritoneal cavity around small intestinal loops in the caudal abdomen; however, small leaks may not be readily apparent on initial radiographs (Fig 4). Repeat radiographs 5 to 10 minutes following administration of the positive contrast medium may be necessary to identify small or slow leaks.

**Urethra**

Urethral rupture is most commonly associated with traumatic pelvic fractures (eg, vehicular), particularly in male dogs. Bite wounds, fractures of the os penis, and bullet wounds are less common causes of urethral rupture in the dog. Urethral rupture in the cat is often associated with feline lower urinary tract disease. Additionally, catheter trauma and forceful urinary bladder expression in attempts to alleviate lower urinary tract obstruction can result in urethral rupture. It is important to recognize that the ability to urinate does not rule out the possibility of bladder or urethral ruptures. Positive contrast urethrography or excretory urography is necessary to diagnose urethral ruptures in dogs and cats; however, excretory urography may not always demonstrate filling of the urethra with contrast medium. Extravasation of contrast medium into the perirethral soft tissues is evidence of urethral rupture or tear (Fig 5).

Initial preparation for positive contrast urethrography is similar to that of positive contrast cystography; however, an additional lateral radiograph of the pelvis with the hind limbs pulled forward is needed to evaluate the penile urethra (Fig 6). Additionally, 5 to 20 ml of 15% solution of water-soluble, nonionic, iodinated contrast medium is recommended. Aseptic urethral catheterization is performed with a balloon-tip catheter. The balloon should be positioned just proximal to the base of the os penis. A 3.5 French side-hole catheter should be used in cats. A lateral radiograph of the pelvis and penile urethra should be made as the final milliliter of contrast medium is infused into the urethra. Infusion of contrast medium should be performed under steady, moderate pressure. Injecting too slowly may not demonstrate the lesion; however, injecting too fast may lead to spasm or trauma. Additional oblique radiographs have also been recommended.

**Prostate Gland**

Acute disorders of the prostate gland include acute prostatitis and prostatic abscesses. Unfortunately, it is difficult to differentiate these prostatic diseases with radiographic findings. Prostatic disease usually results in enlargement of the gland, resulting in cranial displacement of the urinary bladder. However, ventral prostatomegaly may produce craniodorsal displacement of the urinary bladder. If prostatomegaly becomes severe, the colon may become compressed and displaced dorsally. A normal prostate gland should be less than 70% of the pubic-promontory distance on lateral radiographs. A prostate gland larger than 90% of the pubic-promontory distance is suggestive of an abscess, neoplasia, or paraprostatic cyst. Symmetric enlargement of the prostate gland can be caused by prostatitis or prostatic hypertrophy. Prostatic cysts and abscesses often result in prostatomegaly with extension dorsal...
Fig 3. Lateral abdominal radiograph demonstrating decreased serosal margin visualization. The urinary bladder shadow is not visible and urinary bladder rupture should be considered.

to the urinary bladder and well-defined margins. Gas within the prostate gland must be differentiated from a superimposed bowel loop or from a previous negative or double-contrast urethrogram. If it is not due to these causes, bacterial cystitis from gas-forming bacteria may be the source. Unlike prostatic abscesses and cysts, severe enlargement is not usually present in acute prostatitis or prostatic neoplasia. Additionally, acute prostatitis and prostatic neoplasia are often characterized by rough, indistinct margins. Bacterial prostatitis can cause mild to no prostatic enlargement, which may be symmetric or asymmetric. Indistinct prostatic borders, especially cranioventrally, have also been described. Bacterial prostatitis can also result in generalized peritonitis. Multifocal areas of mineralization in the prostate gland have been described in both chronic prostatitis and prostatic carcinoma.

Retrograde urethrocystography has been used to help classify prostatic disease. The procedure is similar to positive contrast cystography. Following distension of the urinary bladder, the urethra is infused with contrast medium using an end-hole balloon catheter to maximize urethral distension. Because of the diffuse nature of prostatitis and hypertrophy, the urethra is usually seen passing through the center of an enlarged gland. Narrowing of the prostatic urethra has been observed with prostatic abscesses, benign prostatic hypertrophy/hyperplasia, paraprostatic cysts, prostatic carcinoma, transitional cell carcinoma of the prostatic urethra, and periprostatic sarcoma.

Fig 4. Lateral radiograph of a positive cystogram (same patient as figure 3). Positive contrast medium is visible outlining multiple small intestinal loops consistent with urinary bladder rupture. Craniodorsal luxation of a coxofemoral joint is also noted.
Fig 5. Lateral radiograph of a urethrogram on a 6-month old mixed breed canine with a history of hematuria following castration. Note the extravasation of positive contrast medium into the soft tissue consistent with rupture of the penile urethra.

one report, prostatic abscessation resulted in increased urethral diameter, but this was not proven in further studies. Neoplasia is associated with irregular mucosal margination and luminal disruption of contrast media in the urethra. An undulating margin to the urethral mucosa has also been observed with benign prostatic hypertrophy/hyperplasia, prostatitis, prostatic abscesses, and prostatic neoplasia.

The characteristics of the urethroprostatic reflux can also be useful in differentiating prostatic disease. Large amounts of urethroprostatic reflux with an irregular appearance are suggestive of neoplasia. Nonneoplastic diseases (eg, prostatic abscesses and cysts) are more likely to result in a pool of urethroprostatic reflux with rounded margins. In some cases, the urethroprostatic reflux communicates with a prostatic abscess, resulting in filling with contrast medium.

Prostatic neoplasia and abscesses can cause sublumbar lymphadenopathy, which is visible radiographically as increased soft tissue opacity ventral to the caudal lumbar vertebrae and sacrum. A proliferative bony response on the pelvis or caudal lumbar vertebral bodies, with or without bone lysis, is suggestive of metastatic prostatic neoplasia (Figs 7 and 8).

Abnormalities of the Peritoneal Cavity

Peritoneal Effusion

Under normal conditions in adult, noncachectic dogs and cats, the serosal surfaces of the small intestines are adequately visualized because of the presence of peritoneal fat. Decreased visualization of the serosal margins can be caused by peritoneal effusion, hemorrhage, emaciation, or lack of fat in young animals. A study of 65 cats determined that the most common cause of peritoneal effusion in older cats and kittens was neoplasia and right-sided heart failure, respectively. Additional diseases that result in peritoneal effusion include cardiovascular, hepatic, and renal disease. Less common causes include
Fig 7. Lateral abdominal radiograph of a 10-year old mixed breed canine that presented for lumbar back pain. The urinary bladder is distended and mineralization is visible in the prostate gland. Additionally, increased soft tissue opacity containing irregular areas of mineralization is present ventral to the sixth and seventh lumbar vertebrae and is ventrally displacing the colon. Lysis and bony proliferation of the caudal sacrum are also present. Nodular soft tissue opacities are present in the caudal lung fields. These radiographic findings are consistent with prostatic neoplasia and metastasis to the sublumbar lymph nodes, sacrum, and lungs.

Fig 8. Lateral abdominal radiograph of a 10-year old mixed breed canine that presented for lumbar back pain. The urinary bladder is distended and mineralization is visible in the prostate gland. Additionally, increased soft tissue opacity containing irregular areas of mineralization is present ventral to the sixth and seventh lumbar vertebrae and is ventrally displacing the colon. Lysis and bony proliferation of the caudal sacrum are also present. Nodular soft tissue opacities are present in the caudal lung fields. These radiographic findings are consistent with prostatic neoplasia and metastasis to the sublumbar lymph nodes, sacrum, and lungs.
Fig 9. Lateral abdominal radiograph demonstrating pyometra. Note the tubular soft tissue opacity structure in the middle and caudal abdomen consistent with an enlarged uterus.

Fig 10. Ventrodorsal radiograph of a dog determined to have a pancreatic mass. A positive contrast gastrogram has been performed. Note the mass effect between the pylorus and the proximal duodenum. Positive contrast dilation of the proximal duodenum is also present. Similar radiographic findings can be seen with pancreatitis.

Fig 11. A lateral radiograph of the abdomen with the patient in right lateral recumbency demonstrating gastric dilatation-volvulus (GDV). The stomach is severely dilated with gas and there is dorsal displacement of the pylorus producing compartmentalization.
pleural space. Pleural and peritoneal effusion together due to neoplasia or cardiac disease yield a poor prognosis.

Liver
Hepatic neoplasia (primary and metastatic) can cause acute abdominal distress and radiographic changes in the liver. Primary hepatic neoplasia often produces an asymmetric cranial abdominal mass with caudal displacement of the stomach. Concurrent loss of serosal margination caused by peritoneal effusion is also common. Less often, hepatic neoplasia causes symmetric hepatic enlargement, or no radiographic abnormalities. The most common canine primary hepatic tumors in order of prevalence are hepatocellular carcinoma, hemangiosarcoma, and biliary carcinoma. The most common feline primary hepatic tumors include biliary carcinoma, hepatocellular carcinoma, hemangiosarcoma, and other sarcomas. Lymphoma should also be considered as a differential for hepatic neoplasia.

Common causes of focal hepatic enlargement include cysts,
granulomas, abscesses, neoplasia, regenerative nodules, and hematomas. Although rare, liver lobe torsion can alter the position of the liver and look similar to a focal hepatic mass with displacement of adjacent organs. These changes may not always be visible if peritoneal effusion is present.

Although not specific for hypoadrenocorticism, a small liver (indicated by cranial displacement of the stomach) can be identified on abdominal radiographs of animals with naturally occurring hypoadrenocorticism. Additional radiographic findings in animals with hypoadrenocorticism include a small heart, caudal vena cava, and pulmonary vessels. A less common radiographic finding is a gas-dilated thoracic esophagus. Other differentials for a small liver include a portosystemic shunt, cirrhosis, acute and subacute hepatic necrosis, diaphragmatic hernia, and congenital or developmental disorders.

The presence of gas within the liver is considered a significant finding. Gas can accumulate within the portal vessels, bile ducts, gallbladder, and hepatic parenchyma. Branching gas opacities in the liver parenchyma represent gas within the portal vessels secondary to gastric torsion or severe necrotizing gastroenteritis. This radiographic finding carries a grave prognosis. Gas within the gallbladder and bile duct is indicative of emphysematous cholecystitis and cholangitis. Such a finding should alert the clinician to the possibility of diabetes mellitus, although it may be found with previous gastrointestinal or hepatic surgery. Radiographically, hepatic abscesses produce focal, irregularly shaped, circumscribed gas opacities. Although hepatic abscesses are rare in dogs, they may be found in puppies with umbilical infections and in adult dogs because of hepatic trauma, neoplasia, or an extrahaepatic infection. Hepatic abscesses have been described in two dogs with diabetes mellitus. Both dogs had hepatomegaly, but only one dog had radiographic signs suggestive of a hepatic mass. Hepatic abscesses in diabetic patients may be associated with a compromised immune system. An additional abdominal radiographic finding that may be seen with diabetes mellitus is emphysematous cystitis. Gas may be visualized in the urinary bladder lumen, wall, or bladder ligaments.

Round mineral opacities in the right cranioventral region of the liver may represent choleliths; however, cholelithiasis and choledocholithiasis are uncommon in dogs and cats. Often, the small size or insufficient mineralization of choledocholiths limits their visibility on radiographs. Cholelithiasis and choledocholithiasis are more easily and appropriately evaluated with ultrasonography. Additional differentials for solitary or miliary mineral opacities within the liver include granulomas, chronic hematomas, abscesses, neoplasia, regenerative nodules, and chronic hepatopathies.

Spleen

Splenic torsion is an acute condition that can be associated with GDV, or can occur as a single disease process. Great Danes and German Shepherd dogs are at an increased risk of splenic torsion, and males are more frequently affected. Several theories have been proposed pertaining to the etiology of splenic torsion. One theory is that multiple episodes of gastric dilation lead to laxity of the gastrosplicenic and splenocolic ligaments. An alternative theory is that splenic displacement is secondary to splenic congestion from gastric dilation. Others have proposed that splenic torsion predisposes animals to gastric dilation by interfering with the passage of gastric contents, and by stretching the hepatoduodenal and hepato gastric ligaments. In a study of 19 cases of splenic torsion, all patients had splenomegaly on abdominal radiographs. Displacement of adjacent abdominal organs was also common. Additional...
radiographic findings associated with splenic torsion include abnormal location and shape of the spleen, loss of abdominal detail, and intrasplenic gas. The splenic gas may be caused by necrosis and gas-producing bacteria. Peritoneal effusion may occur 1 to 2 days after splenic torsion. Although it is not always visible, a lateral radiograph may show a folded, C-shaped spleen in the central abdomen.

Besides splenic torsion, an additional cause of acute abdominal distress is a splenic mass. Splenic neoplasia, such as hemangiosarcoma, is a common cause of splenomegaly that may produce generalized or localized enlargement. However, a localized splenic mass or generalized splenomegaly is nonspecific, and must be differentiated from a hematoma, inflammation, abscessation, or nodular hyperplasia. The most common cause of a midabdominal mass on lateral radiographs of the canine abdomen is a splenic mass. In some cases, decreased serosal margin visualization associated with peritoneal effusion or hemorrhage may make visualization of the splenic mass difficult. However, intestinal displacement may suggest a mass.

Uterus

Uterine abnormalities that result in an acute abdominal distress include pyometra and uterine torsion. Both conditions cause uterine enlargement. Usually the uterus is not visible until it is larger than the adjacent small intestinal loops. Compression
radiography may be beneficial, because it displaces superimposed bowel loops, allowing better visualization of the uterus between the colon and urinary bladder on lateral views. Generalized uterine enlargement results in a soft tissue tubular enlargement extending caudally to the pelvic inlet (Fig 9). Generalized uterine enlargement is nonspecific, and differentials include early pregnancy, pseudopregnancy, pyometra, pyometra, mucometra, uterine torsion, uterine entrapment, and uterine adenomyosis. Even with the presence of fetal mineralization and uterine enlargement consistent with pregnancy, uterine torsion cannot be ruled out. In fact, pregnancy has been suggested to be a contributing factor for uterine torsion. Although uterine torsion is uncommon, high mortality rate is associated with this condition. Potential complications include peritonitis, septicemia, endotoxemia, and disseminated intravascular coagulopathy. The most common radiographic finding is in cases with pyometra is uterine enlargement. Less common radiographic findings include ascites, a solitary abdominal mass, or no radiographic abnormalities. Localized uterine enlargement can occur with a localized pyometra, neoplasia, cystic endometrial hyperplasia, hydrometra, mucometra, uterine stump granulomas and abscesses, cystic uterine remnant, and uterine adenomyosis.

Pancreas
Pancreatitis is a common cause for an acute abdomen. Under normal circumstances, the pancreas is not radiographically visible. The most common findings in a radiographic study of 182 dogs with pancreatitis included increased opacity, decreased abdominal detail, and granularity in the right cranial abdomen on ventrodorsal radiographs. Additional findings included displacement of the pyloric antrum toward the left, a mass medial to the proximal descending duodenum, replacement of the duodenum toward the right, a static gas pattern in the descending duodenum or thickening of the wall of the descending duodenum, a static gas pattern in the transverse colon, and caudal displacement of the transverse colon (Fig 10). Pancreatitis can also result in pleural effusion. Traumatic hemorrhagic pancreatitis has been reported in cats falling from heights. Evidence of pancreatitis was not visible on initial radiographs, but was present by the third day post-trauma. Radiographic findings included a mottled appearance in the ventral abdomen. Dorsal or dorsomedial displacement with corrugation or spasticity of the duodenum was also present.

Stomach
The use of radiography in the diagnosis of GDV is well known. A right lateral radiographic view has been recommended for the best visualization of GDV. A diagnosis of GDV is based on the finding of gas-filled gastric lumen with craniodorsal displacement of the duodenum to the left side of the abdomen on the dorsoventral and right lateral recumbent views. Compartmentalization of the stomach is an additional radiographic sign of GDV, represented by a soft tissue opacity band dividing the gas-distended stomach on the right lateral recumbent view (Figs 11 and 12). The severity and degree of obstruction are dependent on the amount of stomach rotation. Clockwise rotation of the stomach is most common. Additional radiographic findings with GDV include enlargement and displacement of the spleen, gas within the hepatic tissue, compression of the liver, and decreased size of the caudal vena cava and cardiac shadow. Gas dilation of the small intestines from adynamic ileus may be present if there is concurrent aerophagia, pain, and esophageal dilation from GDV. A grave prognosis should be given if gas is visible within the gastric wall. Spontaneous pneumoperitoneum has been described in two dogs with gastric volvulus. Pneumoperitoneum was associated with splenic necrosis and trauma of the gastroesophageal region, and perforation from multiple attempts to pass an oro gastric tube. Additional causes of pneumoperitoneum include recent abdominal surgery, rupture of a hollow viscus, positive end-expiratory pressure, gas-forming organisms, and leakage of air through an abdominal drainage site or through the wall of an intact, but gas-distended stomach.

Zinc toxicosis should be considered in patients with a history of ingesting pennies, or with the radiographic finding of metallic opacities resembling coins within the gastric lumen. Pennies minted after 1983 contain a large amount of zinc. When the copper coating is disrupted, hydrochloric acid reacts with the zinc and can lead to toxicosis. Ointments containing zinc and zinc-coated hardware are also potential sources of zinc intoxication. Gastric ulcers are another cause for an acute abdomen, but can be difficult to visualize and differentiate. Double-contrast gastrography is usually necessary for identification, but can be contraindicated in critical patients. Gastric ulcers may be benign or malignant, and are classified based on the mucosal pattern around the ulcer, degree of penetration, presence of undermining of the mucosa, and the shape of tissue surrounding the ulcer. Benign ulcers are acute or stress ulcers caused by gastric acid erosion of the mucosa. Malignant ulcers are caused by tumor necrosis from neoplasia.

Double-contrast gastrography is recommended for identification of gastric wall lesions (eg, ulcers). Preparation of the patient for the contrast procedure includes fasting and warm water enemas. Lateral and ventrodorsal survey radiographs should be obtained. A total of 2 to 4 ml/kg of body weight of 100% barium sulfate suspension is administered via stomach tube, followed by 10 to 20 ml/kg of room air. The contrast medium is then distributed over the gastric wall by rotating the animal multiple times. Left lateral, right lateral, ventrodorsal, and dorsoventral radiographs of the cranial abdomen are made. To assist in evaluation of the gastric wall, gastric motility can be decreased by the administration of glucagon at a dose of 0.1 to 0.35 mg intravenously.

The most accurate information is obtained when ulcers are visualized in profile. Because of the low number of gastric ulcers recognized in canine patients radiographically, those that are identified should be considered malignant, and require further evaluation (eg, endoscopy). A shallow, irregular crater with adherent contrast medium and abrupt transition from the ulcer mound to normal tissue is suggestive of a malignant ulcer. Malignant ulcers are usually associated with gastric wall thickening.

Small Intestines
Gastrointestinal foreign objects are a common cause of acute abdominal discomfort. Linear foreign objects that can cause intestinal obstruction in dogs and cats include string, elastic tape, rubber bands, nylons, and other cloth materials. Linear foreign bodies result in plication (pleating) of the small intestines. Because of peristalsis, the intestines gather around the foreign object, which is fixed more proximally in the gastrointestinal tract (Figs 13 and 14). The involved intestines are usually in the midventral region on abdominal radiographs.
The presence of small, eccentrically located luminal gas bubbles in the small intestines also suggests a linear foreign object. This may be the only visible radiographic sign if there is decreased serosal margin visualization because of peritonitis.\textsuperscript{44,45} Peritonitis is a more common finding in dogs than in cats with linear foreign objects.\textsuperscript{44} Potential differential diagnoses for patients with radiographic findings similar to a linear foreign object include intestinal hyperperistalsis (secondary to infectious disease or nonspecific causes), peritoneal adhesions from previous abdominal surgery, and intestinal parasites.\textsuperscript{44} Additional differentials in cats include obesity, intestinal lymphosarcoma, and hemorrhagic pancreatitis.\textsuperscript{44}

In addition to linear foreign objects, small intestinal obstruction can be associated with intramural masses, intussusception, and other foreign objects.\textsuperscript{46} These obstructions result in mechanical ileus, recognized by gas or fluid dilation of small intestinal loops. In the dog, the normal small bowel should be no wider than the central portion of the body of a lumbar vertebra, and should not exceed the diameter of twice the width of a rib.\textsuperscript{3} In the cat, the normal small bowel should not exceed 12 mm.\textsuperscript{46} In mechanical ileus, gas dilation of the small intestines is present orad to the obstruction.\textsuperscript{46}

In some cases, intestinal obstruction can cause intestinal perforation, resulting in free gas within the peritoneal cavity. In the absence of recent surgery, this finding warrants exploratory laparotomy. Free abdominal gas can accumulate between the diaphragm and liver, or may outline liver lobes and loops of small intestine (Figs 15 and 16). Additionally, free abdominal gas may appear as multiple small, round gas opacities that are not associated with intestinal loops. Horizontal-beam ventrodorsal radiographs with the patient in left lateral recumbency are recommended to further assess the presence of free abdominal gas within the peritoneal cavity.\textsuperscript{3} On this view, free abdominal gas accumulates beneath the right abdominal body wall.\textsuperscript{3} In right lateral recumbency, gas within the gastric lumen may be misinterpreted as peritoneal free gas (Fig 1/7).

If radiographic signs of intestinal obstruction are not definitive, radiographs can be repeated in 24 hours to re-evaluate the patient. If radiographic signs are still questionable or a partial obstruction is present, an upper gastrointestinal study may be warranted. Survey radiographs should be performed following a 12- to 24-hour fast. However, in patients with acute abdominal distress, laxatives and enemas are contraindicated, as they may lead to additional injury.\textsuperscript{46} If sedation is required, acetylpromazine maleate and ketamine hydrochloride for dogs and cats, respectively, are the recommended sedatives because they have minimal effects on intestinal motility.\textsuperscript{37} A 30% barium sulfate suspension at 10 to 12 mL/kg of body weight is administered by stomach tube.\textsuperscript{37} Alternatively, if intestinal perforation is suspected, 2 mL/kg body weight of nonionic iodinated contrast medium diluted in 8 mL/kg body weight of water should be used.\textsuperscript{37} Lateral and ventrodorsal radiographs of the abdomen should be made immediately following the administration of barium sulfate suspension, and then in 30, 60, 120, and 240 minutes (or until all of the contrast medium has left the stomach and the contrast medium has reached the colon).\textsuperscript{37} The normal small intestinal transit time in the dog is 3 to 4 hours. Mechanical obstruction causes an abrupt stop of the contrast medium or results in over 90% dilation of the intestinal loops proximal to the obstruction.\textsuperscript{37} The intestinal transit time of cats is approximately 1 hour, but can vary from 30 minutes to 3 to 4 hours. Therefore, in cats, radiographs should be made immediately following the administration of barium sulfate solution, then in 15, 30, and 60 minutes. Intestinal transit can be faster with iodinated contrast medium. Therefore, in dogs, radiographs should be taken immediately, and at 15, 30, and 60 minutes after administration of iodinated contrast medium. In cats, radiographs should be taken immediately, and at 5, 15, and 30 minutes after administration.\textsuperscript{46}

Paralytic ileus can cause localized or diffuse ileus, and may be difficult to differentiate from mechanical ileus.\textsuperscript{47} With paralytic or functional ileus, the lumen is patent, and intestinal dilation is caused by vascular compromise or neuromuscular abnormalities.\textsuperscript{46} Localized paralytic ileus can result in dilation of an intestinal loop that does not change position on consecutive radiographs. This intestinal loop is termed a "sentinel loop" and is a significant finding that is considered a sign of a serious abdominal disorder, indicating a localized area of disease adjacent to or involving the small bowel.\textsuperscript{47} Differentials for functional ileus associated with an acute abdomen include parvovirus enteritis, mesenteric volvulus, spinal trauma, or dysautonomia.\textsuperscript{48} Dysautonomia is an idopathic condition that causes loss of autonomic nervous system function. Radiographic findings include aspiration pneumonia, megaesophagus, distended (gas or fluid) stomach and small intestines, and a distended bladder.\textsuperscript{49} Radiographic signs of dysautonomia may be difficult to differentiate from mechanical obstruction.

An additional differential for an obstructive pattern of the distal small intestines is an intussusception. A tubular soft tissue structure with gas or fluid dilation of the small intestines proximally is suggestive of an intussusception, but it can be difficult to diagnose unless sufficient intraluminal gas is present in the region of the lesion. Lack of gas in the cecum and ascending colon is also suggestive of an ileocolic or ileocecal intussusception.\textsuperscript{47} Intussusception can appear similar to a foreign body obstruction, neoplasia, mesenteric torsion, or severe enterocolitis.\textsuperscript{49} In a report of 45 cases, ileocolic intussusceptions were the most common.\textsuperscript{49} The radiographic signs associated with ileocolic intussusception include a soft tissue opacity structure caudal to the stomach and displacement of the small intestines caudally and to the right. Gas dilation of the small intestinal loops proximal to the intussusception is most commonly present on the opposite side of the abdomen.\textsuperscript{49} If a contrast study is necessary, a positive contrast barium enema is the recommended procedure to evaluate for ileocolic and cecocolic intussusception. This is because of the prolonged time necessary to reach the distal small intestines and colon with an upper gastrointestinal study, as well as decreased motility that may be associated with ileus.\textsuperscript{40}

Before a barium enema is performed, the patient should be fasted for 24 hours and warm water enemas administered at least 2 hours before performing the study. Lateral and ventrodorsal radiographs of the abdomen, including the pelvic canal, should be obtained before anesthesia to ensure that adequate evacuation of feces has been achieved. General anesthesia is necessary for this procedure. A 15% barium sulfate suspension should be used at a dose of 10 to 20 mL/kg of body weight.\textsuperscript{37} A balloon catheter is inserted into the rectum, and the balloon is distended and pulled caudally to form a seal. The barium suspension should be administered slowly by gravitational flow. A survey radiograph is recommended after administration of one-half of the dose of barium suspension to evaluate for adequate filling. Additional barium can be administered if necessary. Following distension of the colon, left lateral, right lateral, and ventrodorsal radiographs are made. Ventrodorsal oblique ra-
diagrams have also been recommended. Following the procedure, removal of contrast medium is recommended. In an ileocolic intussusception, pleating of the involved portion of the colon results in a filling defect within the barium contrast distended colon (Fig 18). This filling defect may have a "coil spring" appearance. Lack of filling of the cecum is suggestive of cecal inversion. Further descriptions of contrast procedures of the colon and interpretive principles are discussed elsewhere.

In conclusion, abdominal radiography can be very beneficial for evaluating patients with an acute abdomen. Although ultrasound is becoming more available and can support radiographic findings, radiography continues to be a very valuable diagnostic tool. Radiography is an accessible and familiar method of evaluating skeletal and soft tissue disorders that may be causing an acute abdomen.

References