ABDOMINAL RADIOGRAPHY IN THE ACUTE ABDOMEN
Perspectives from a radiology resident, current research and possible future directions

Kimberly Cronin, DVM
Department of Small Animal Clinical Sciences
College of Veterinary Medicine
Veterinary Medical Center
Michigan State University
East Lansing, MI 48864

Introduction

The term *acute abdomen* is defined as the sudden onset of abdominal pain or discomfort. Because acute abdomens can be a clinical manifestation of myriad conditions, cases of acute abdomen can often be diagnostic challenges. Radiography plays pivotal role in the initial assessment of dogs with acute abdominal signs. The ability to obtain a rapid and accurate diagnosis is paramount in guiding appropriate medical and or surgical intervention. Survey radiography and abdominal ultrasonography (if available) are the current standard imaging modalities for evaluation of dogs with acute abdominal signs. Often radiographs alone can give valuable information about whether surgical intervention is warranted. Conditions readily diagnosed on survey films that will be discussed today include free gas, peritoneal effusions, GDV, small intestinal obstruction, splenic torsion, masses, body wall or diaphragmatic herniation and calculi.

Radiographic positioning and projections

Positioning is very important in acute abdominal pain and gastrointestinal evaluation. The abdomen contains a valuable inherent contrast medium—gas. Thus, by routinely acquiring left and right lateral radiographs in addition to the ventrodorsal view, redistribution of bowel gas between the two lateral views can provide valuable additional information that can make the difference between obtaining the diagnosis or not. There is no reason to limit the number of projections acquired routinely, especially with direct digital system where the image is available instantly and there are no expendable supplies. Not acquiring both right and left lateral views routinely in addition to the ventrodorsal view will result in some missed diagnoses.

One major difference between left and right lateral abdominal radiographs in dogs and cats is the appearance of the stomach. When the patient is in right recumbency, the pylorus will usually contain ingesta or fluid. If gas is in the stomach, the gas will rise and collect in the body and fundus of the stomach. It is important to remember that in right lateral views, especially in dogs, a fluid filled pylorus it can take on the appearance of a mass or foreign object. Alternatively, when the patient is placed in left recumbency, gas will rise and fill the pylorus and the fluid will usually gravitate to the fundus. Gas in the pylorus on the left lateral can highlight pyloric soft tissue opacity material that summates with fluid on the right lateral projection. Recent research supports acquiring a left lateral projection first. Hart et al 2014 showed that dogs first placed in left lateral recumbency were significantly more likely to have duodenal gas on the subsequent ventrodorsal and right lateral radiographic projections compared to dogs first placed in right lateral recumbency.
It is important to include the entire abdominal cavity in the image. On the ventrodorsal projection the field of view should extend from just cranial to the diaphragm to a few centimeters caudal to the coxofemoral joints. The pelvic limbs should be flexed into a so-called frog-leg position rather than being pulled caudally to avoid skin fold artifacts. For lateral projections, the pelvic limbs should not be pulled caudally but should be kept perpendicular to the spine. This reduces crowding of the abdominal organs by relaxing the abdominal wall.

The body habitus is an ancillary factor that has a significant effect on radiography. It is critical for some fat to be present to distinguish organs from one another. In emaciated or young animals, reduced fat results in loss of serosal margin detail. Fat is more radiolucent than soft tissue and provides contrast between organs. Cats often have a particularly large collection of fat in the falciform ligament which can be misinterpreted as peritoneal fluid. This is not fluid as there is a lack of border effacement of the adjacent liver and jejunum. Cats also accumulate a large amount of fat in the omentum and midabdomen which may crowd the jejunum and may mimic a linear foreign body. However other signs of linear foreign body obstruction such as eccentric gas bubbles or bowel distention are not noted.

Cutaneous lesions can also have a significant effect on the appearance of radiographs. Normal superficial structures superimposed on the abdomen and cutaneous lesion are not misinterpreted as a lesion as often as they are in thoracic radiographs. The exception being on the caudal aspect of the abdomen in ventrodorsal radiographs of male dogs, superimposition of the prepuce and os penis often mimic masses.

It is important to evaluate the whole radiograph, including the extrabdominal skeletal structures. Spinal pain may often mimic abdominal pain. It is important to look for evidence of intervertebral disk disease, diskospondylitis, and other skeletal conditions. There are various schools of thought when evaluating radiographs. Some propose evaluating the spine and skeletal system first, so it does not get missed; Others recommend evaluating it last. Still, others recommend evaluating the image as a whole first and if there is an obvious abnormality noted to evaluate this first, as it may be distracting and hinder detailed evaluation of other areas. However, one should be cautioned to not cease looking after the obvious abnormalities are detected. Often times we get satisfied with finding an abnormality and miss subtle radiographic changes that may influence prognosis or change to course of treatment.

Peritoneal space.

Fluid within the peritoneal cavity causes a loss of the differential opacity interface between soft tissue and fat and therefore a loss of contrast between organs. Causes for loss of intraabdominal contrast include lack of fat, peritoneal effusion, peritonitis, and peritoneal neoplasia. Loss of serosal detail with an adequate body habitus, peritoneal effusion, peritonitis and neoplastic effusion should be considered likely. A small volume of fluid may not obscure serosal margin detail completely. Therefore, organ margins may still be visible when intraperitoneal fluid is present. A small volume of peritoneal fluid may produce a mottled or hazy appearance with curvilinear soft tissue opacities. This effect can be quite subtle and one method proposed is to compare the peritoneal detail with the retroperitoneal detail as they should be identical.

Gas within the peritoneal space causes an increase in contrast between organs. The two most common causes of intraperitoneal gas are penetration of the abdominal wall, either by surgery or by penetrating wounds, and perforation of the bowel. However, not all bowel perforations lead to free abdominal gas. If surgery has not been performed and there is no
evidence of a penetrating trauma a perforated bowel should be suspected and exploratory laparotomy is recommended. Perforation can be secondary to gastrointestinal ulceration, foreign bodies and neoplastic disease. Other causes of pneumoperitoneum that does not redistribute with changing projections includes emphysematous cystitis, or hepatobiliary abscess.

A small volume of free abdominal gas can be difficult to recognize on conventional radiographs as the gas bubbles may be small and irregular in shape and may overly bowel. Free abdominal gas usually floats to the highest point within the abdomen. In lateral recumbency, this is usually under the caudal aspect of the ribs or in the midabdomen. The concurrent presence of abdominal effusion may make recognition of the gas bubble easier because the fluid provides a more uniform, homogeneous soft tissue background opacity. A horizontally directed beam can isolate the gas from superimposed structures.

**Normal gastric radiographic assessment**

As discussed earlier positioning is of utmost importance. The stomach can be consistently identified on survey radiographs. Variations in the stomach appearance in the dog based on the shape of the thorax and cranial abdomen and gastric distention. Some general guidelines can be followed, on lateral projection the axis of the stomach is either perpendicular to the spine, parallel to the ribs, or somewhere between these angles. On the lateral view, the pylorus may be superimposed over the body or located slightly cranial to the body. On the ventrodorsal view of the dog, the pylorus is to the right of midline and the cardia, fundus, and body of the stomach are located to the left of midline. The pyloric sphincter usually is located in the right cranial abdominal quadrant at approximately the level of the tenth or eleventh ribs. The pylorus may be located closer to midline in young animals. On ventrodorsal projection, the long axis of the stomach is usually perpendicular to the spine or in U shape.

The feline stomach creates a J shape on the ventrodorsal projection with feline the pylorus located at or near the midline. In 2005 Heng et al showed that fat was responsible for an intramural radiolucent band in the stomach wall can be seen on abdominal radiographs of cats without concurrent clinical gastrointestinal signs.

**Abnormal gastric radiographic findings**

Abnormalities include abnormal positioning and displacement. The gastric position is affected by surrounding organs and thus can provide valuable information, for example the gastric axis can be displaced caudally with hepatomegaly. Cranial displacement of the stomach may also occur with rupture of the diaphragm and herniation of the liver, part of the liver or may indicate a small liver. Abdominal masses that originate caudal to the stomach may distort the shape of the stomach or they may displace the stomach to the right or left. They do not displace the stomach cranially because of the presence of the liver.

Gastric foreign bodies can be straightforward if they are radiopaque, such a metallic opacities or a diagnostic challenge. Positioning as discussed above can be extremely important to utilize gas in the stomach and highlight non radiopaque foreign material. If the stomach is gasless room air can be administered to create a negative gastrogram and identify soft tissue material. A small amount of barium can also be administered to help identify nonradiopaque material. Remember that this is not a true upper gastrointestinal contrast study and transit time cannot be evaluated and without a proper dose, mucosal abnormalities may also be missed. Barium creates a different appearance depending on the material. For example a solid ball creates a round, discrete filling defect within the barium however a rag or sock will absorb and
retain the barium due to its permeability. The stomach may occasionally contain nondescript radiopaque material of questionable significance. If the patient is stable it may be reasonable repeat radiographs in 12-24 hours and evaluate if this abnormality persists. The repeated radiographs may shed light on digestibility of material and potential transit.

Acute gastric dilation and gastric volvulus (GDV) is an emergency condition and radiography is of paramount importance. GDV produces gaseous distention of the stomach. Although both fluid and ingesta may also be noted, gas distention is the predominant abnormality in these conditions. Gastric dilation/volvulus is differentiated from acute gaseous dilation by the presence of gastric malpositioning. The radiographic appearance of the stomach varies depending on the type and degree of rotation and the amount of dilation.

The major radiographic signs of GDV is gas distention of the stomach (more gas than fluid) and the pylorus is usually displaced dorsally and to the left. The spleen follows the greater curvature toward the right due to adherence with the gastroplenic ligament. This is most conspicuous on the right lateral projection as the volvulus alters anatomy and the pylorus is gas filled on the right lateral projection. Although both laterals are recommended, in unstable patients it is prudent to obtain the right lateral first. The stomach will also become compartmentalized, soft tissue bands project into or across the gas-filled lumen of the rotated stomach from folding of the stomach. As the stomach progressively distends the wall will become thinner. The wall should be carefully examined for gas within the wall (pneumatosis). Gastric pneumatosis or pneumoperitoneum may indicate gastric necrosis. However, trocharization of the stomach may create similar radiographic signs. Gastric wall necrosis can be seen without pneumatosis. Other changes that may be noted concurrently with gastric volvulus include splenomegaly, megaesophagus, reflex paralytic ileus of the small intestine, and hypovolemia (small vessels and cardiac silhouette) secondary to shock. There may also be a loss of serosal detail due to hemorrhage, as there can be damage to gastric vasculature during rotation.

Small intestinal radiographic assessment

Small intestines should contain about 50% gas and fluid. Gasless small intestine is often noted with enteritis but can also be noted in normal dogs. No specific measurement for normal bowel diameter exists for dogs due to the variation in canine body size and the magnification effects of radiography. There are ratios for relative bowel diameter that use nearby bones as reference structures. The maximal normal diameter for the dog has been reported to be less than 1.6 times the height of the L5 vertebral body at its narrowest point or less than twice the width of the fourth rib. Cats tend to have a more standardized body size. Normal bowel diameter should not exceed 12 mm when the bowel is gas filled or twice the height of the central portion of the L4 vertebral body.

The jejunum and ileum should have approximately the same diameter, the duodenum may be slightly wider. A gas distended duodenum can be noted with pancreatitis (sentinel loop sign). The descending duodenum is easiest to appreciate on the left lateral projection and on a ventrodorsal projection. It lies lateral and in the right cranial abdomen on the ventrodorsal projection. Other signs of pancreatitis include: increased soft tissue opacity in the cranial right abdomen, focal decreased soft tissue detail, right cranial abdomen soft tissue mass effect caudal to stomach, and displacement of adjacent intestinal structures. Radiographs may also be normal. Attempts to judge the thickness of the intestinal wall on survey radiographs are unreliable. An
empty bowel loop with a small volume of intraluminal air should not be mistaken for a pathologically thickened segment.

There are many diseases that result in small intestinal dilation. Ileus is defined as a failure of intestinal contents to pass through the tract. Ileus can be function (paralytic) or mechanical (obstructive). In functional ileus, the bowel remains patent however contractions of the bowel stop as a result of neuromuscular or vascular abnormalities within the bowel wall. On the contrary mechanical ileus is caused by physical obstruction of the bowel. The small intestinal lumen can be occluded by foreign objects, intussusception, mural mass, or extrinsic lesions. Intussusception may be seen on survey radiographs as mechanical obstruction or a tubular soft tissue opacity. However ultrasound gives a more classic appearance.

Small intestinal size is very important when evaluating the bowel for mechanical ileus and to determine if surgery is necessary. Radiographic signs of mechanical obstruction include gastric and intestinal dilatation by gas and/or fluid, two populations of bowel (normal and distended), abnormal shape of intestinal loops (such as, plication, stacking or bunched loops and hairpin bends), foreign material, and the gravel sign. Some consider the localized dilation of the intestine as the key radiographic sign. However, the length and degree of dilatation may vary depending on the site, duration, and completeness of an obstruction. If the patient is losing fluid via vomitus distention may not be seen (i.e. duodenal obstruction).

A recent study (2013) revealed that, as a clinician gains experience in evaluating abdominal radiographs, qualitative assessment of bowel size will become just as accurate as measurement techniques using ratios. (Ciasca et al.) Limitations included it being retrospective and only lateral images were evaluated (right verse left was no specified). Another study, (Finck et al) just recently released, is another retrospective which proposed measuring the average diameter of the small intestines, as well as, small intestinal maximum/minimum along with the SI max/L5. They evaluated both lateral and ventrodorsal projections. Fifty dogs with gastrointestinal clinical signs and abdominal radiographs were recruited from records. Findings indicated that dogs with SImax/L5 >2.4, SImax/SImin >3.4 and SImax/SIave >1.9 are very likely obstructed, particularly if segmental dilation is present. Dogs with SI max/L5< 1.4, SImax/SImin <2, and SImax/SIave <1.3 values are very unlikely to be mechanically obstructed. Dogs with ratios falling between these thresholds may need further testing (such as contrast radiography or ultrasound) unless other signs justify surgical exploration or endoscopy.

When the entire length of bowel is moderately to severely dilated with fluid and gas, a diagnosis of mesenteric torsion or volvulus must be considered. Mesenteric volvulus results in occlusion of the cranial mesenteric artery, leading to ischemic necrosis, gastrointestinal toxin release, and shock. Often times the initiating event is unknown. Large breed dogs may be overrepresented as well as dogs with pancreatic insufficiency. Many dogs have no historical gastrointestinal signs but present as an acute abdomen

Large bowel radiography

The canine cecum is normally gas filled, semicircular and compartmentalized. The cecum joins the colon through a cecocolic junction. The intraluminal gas and characteristic shape allows recognition of the canine cecum reliably. It is usually in the right midabdomen on most survey radiographs. The feline cecum is a short, conelike diverticulum of the colon and is rarely visible on survey radiographs. The shape of the colon is similar to that of a question mark or a shepherd’s crook.
Radiopaque heterogeneous feces and gas, usually present in the colon allows identification of at least part of the bowel. Normal large bowel content usually has a characteristic pattern of fine and evenly distributed gas bubbles, which is helpful in differentiating the colon from small intestinal loop. Similar to small intestines, wall thickness cannot be evaluated from survey radiographs.

**Radiographic findings in large bowel abnormalities**

Disease affecting the large bowel may produce alterations in radiopacity, size, shape, and location of the colon. Function can be implied but not directly evaluated radiographically, based on the quantity or location of feces. A homogenously fluid filled colon is suggestive of diarrhea. A soft tissue mass or an intussusception also appears as a homogeneous soft tissue radiopacity however a curved gas/soft tissue interface will often be noted at the edge of the intussusception (meniscus sign).

The diameter of the colon is influenced by fecal contents. The diameter of the normal canine colon should be less than the length of the body of L7. Various measurements have been reported with cats. In cats without gastrointestinal disease maximal colonic diameter should be approximately 2.2 times the small intestinal diameter and approximately 2.8 times the length of the cranial end plate of the second lumbar vertebra. In another study in cats, it was determined that a colon diameter/L5 length ratio of less than 1.28 indicates a normal or constipated colon, whereas a value of more than 1.48 is indicative of megacolon. Similar to mesenteric volvulus a large, gas distended, displaced colon, +/- peritoneal effusion, a colonic torsion/volvulus should be considered, although the condition is rare.

**Contrast Radiography**

Contrast studies of the gastrointestinal tract can be used to identify the location of the bowel (e.g., displacement through hernias), to determine patency of the lumen, to identify perforation, and to identify irregularities in the contrast medium/mucosal interface. The concept of gastrointestinal contrast studies has been limited typically to the use of positive-contrast agents. However, the inherent gas contrast in the stomach and bowel should be used to full advantage as a contrast medium when present. Barium may be therapeutic and have a mucosal protective effect. Contrast studies can be used to examine the luminal surface, outline a foreign body, and monitor transit time. Probably its greatest usefulness for the general practice situation is the identification of abnormal bowel location and complete bowel obstruction. Positive contrast studies are contraindicated if there is an obvious obstruction on survey radiographs and perforation.

In order to gain the most information the study must be properly performed. Survey radiographs should always be performed to assess patient preparation, establish radiographic technique, and possibly identify the problem. An orogastric tube should be used to administer Barium sulfate suspension. Ideally, with the patient on the x-ray table ready for radiography. The esophageal placement should be verified either with fluoroscopy, survey radiography or palpation. Barium given orally without an orogastric tube often results in suboptimal distention of the stomach. Liquid barium is recommended over Barium USP powder mixed with water. The dosage is **5-12 mL barium/kg body weight**. Not administering enough barium is a common mistake and a common complaint with teleradiology reading of upper gastrointestinal contrast studies. Small dogs typically need the high end of the dosage range, and large dogs may need only the low end. A 100-lb dog gets at least 500 mL of barium. Before removing the tube, instill
a small volume of air to clear the tube, then kink the tube before removal to prevent leakage of barium into the trachea.

A radiograph should be obtained immediately after the tube is removed. All four views are recommended and additional radiographs (with or without obliques) should be made pending the results of the initial radiographs. It is recommended to continue making radiographs (usually right lateral and ventrodorsal) until the majority of the barium is no longer seen within the stomach and is noted in the colon. A small amount of residual barium coating the mucosa can be noted normally. However a focal area of barium retention is suggestive of ulceration. After administration of barium, gastric emptying should start within 15 minutes in most normal patients. During gastrography with barium sulfate, the stomach generally empties within 1 to 4 hours in dogs. Rapid emptying of the stomach has no clinical significance, whereas delayed emptying is potentially of much greater significance. Barium may also be retained of foreign material.

A pneumocolonogram can be performed to differentiate small verses large bowel distention. Pneumocolonograms are easy to perform using a red rubber catheter and 1-3 ml/kg of room air. Place animal in right lateral recumbency unless a portosystemic shunt is suspected. Diaphragmatic hernia is always a concern with abdominal trauma. Positive-contrast peritoneography can be used to identify loss of diaphragmatic integrity. To use this technique, 1 ml/kg of a triiodinated contrast medium should be injected into the peritoneal space to help visualize the outline of the diaphragm. It may be helpful to tip the patient cranially and wait 10 minutes before radiographing to insure spread of contrast agent. If contrast material is noted in the pleural space and there is an irregularity of the margin of the diaphragm a diaphragmatic hernia is likely.

Contrast studies can also be used to assess the kidneys, ureters, and urinary bladder. These studies are particularly valuable when looking for ruptures or tears within the urinary system. Positive-contrast cystography is the procedure of choice to demonstrate bladder tears or ruptures. To conduct this contrast study, the bladder should be evacuated and a 20% organic iodide compound injected through a urethral catheter. Urethral integrity can be assessed using contrast urethrography. It is recommended to use a balloon-tipped catheter (to prevent reflux of the medium) to inject 10 to 15 ml (in dogs) or 5 to 10 ml (in cats) of an organic iodide contrast medium.

Organomegaly and masses

The abdomen should also be evaluated for mass effects and Organomegaly. Displacement of normal structures may be seen. Hepatomegaly is characterized caudal deviation of the gastric axis. A large tubular structure located between the urinary bladder and colon in a female patient may be suggestive of pyometra. Splenomegaly may also be found on survey radiographs. Differentials for splenomegaly in a dog is extensive and includes but is not limited to infectious diseases, extramedullary hematopoiesis, neoplasia, hematoma, and torsion. Compared with the dog, generalized splenomegaly in the cat is most commonly caused by neoplastic infiltration, primarily lymphosarcoma and mast cell tumors. The medical history should be considered because administering certain drugs such as thiobarbiturates may also result in splenic enlargement.

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Splenomegaly occurs when the spleen rotates around its mesenteric axis. This resulting in complete occlusion of venous drainage and eventual arterial occlusion. The spleen subsequently becomes enlarged and may be noted in an abnormal location. In a classic splenic
torsion a reverse C-shape on the lateral view may be noted. However it may simply appear as a mass in the ventral abdomen. It also commonly has accompanying peritoneal effusion. On the ventrodorsal projection the spleen may not be visualized in the normal left craniodorsal location because of the malposition. Ultrasonography (Doppler) or computed tomography has been used in the confirmation of splenic torsion prior to surgical intervention. Other differentials for splenic masses include benign and malignant neoplastic and hematomas. These cannot be differentiated via radiography alone.

**Calculi**

Ureteral, cystic and urethral calculi can often cause obstructions and be a source of pain. Calcium oxalate and struvite can be usually be seen readily on survey radiographs. One may wish to performed a lateral with the pelvic limbs displaced cranially to remove superimposition of the limbs as the fabella can often times resemble urethral calculi.

**Ultrasonography**

Abdominal sonography is also used commonly to assess the canine and feline abdomen, and it has found many applications in these species. However, in dogs and cats, sonography should not be viewed as a replacement for abdominal radiography. Sonography provides for real-time assessment of organ texture and blood vessels that cannot be obtained with radiography, but sonography does not provide for a global assessment of the gastrointestinal tract or organ sizes. The quality of the information obtained from an abdominal ultrasound examination is highly dependent on the abilities of the operator. Even with its limitations ultrasonography can be very helpful in cases of acute abdomen where the radiographic signs are not clear and often leads to a definitive diagnosis. Ultrasonography is noninvasive and it can facilitate collection of abdominal fluid and help guide fine-needle aspiration of abdominal structures. It is helpful with identification/confirmation of intussusceptions, linear foreign bodies, gallbladder mucoceles, splenic torsions, pancreatitis etc. Discussing the ultrasonographic findings of all potential causes of acute abdomen is beyond the scope of this talk and hence were incorporated into the various sections.

**Future directions**

Recent studies have looked into using CT for diagnosing the acute abdomen. However the availability and need for sedation/anesthesia hinder it from being a gold standard at this time.

**In conclusion:**

Although the acute abdomen can be a diagnostic challenge radiographs alone can give valuable information about whether surgical intervention or medical management is warranted. Conditions readily diagnosed on survey films include free gas, peritoneal effusions, GDV, small intestinal obstruction, splenic torsion, masses, body wall or diaphragmatic herniation and calculi (i.e., urethral, ureteral, or cystic). Contrast studies may also beneficial in diagnosing acute abdominal diseases. Ultrasonography and CT (in the future) may be warranted when the radiographic signs are not clear.
REFERENCES

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