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Refereed Peer Review

Ultrasound Evaluation of Equine Gastrointestinal Disorders

FOCAL POINT

★ Transabdominal ultrasonography is a safe tool that can be used to complement traditional approaches to diagnosing colic or gastrointestinal disorders in horses.

KEY FACTS

- Transabdominal ultrasonography is recommended when rectal palpation is prohibited, p. 253.
- Portions of the stomach and intestines can be visualized and disease processes involving the peritoneal lining or abdominal cavity evaluated using transabdominal ultrasonography, p. 255.
- A thorough knowledge of the topographic anatomy in horses is necessary to accurately interpret ultrasound images; scanning normal horses can provide experience, p. 255.
- A definitive diagnosis is rarely obtained with transabdominal ultrasonography; however, some very useful information about the process of gastrointestinal diseases may be obtained, p. 258.

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ABSTRACT: Certain disease processes affecting the equine gastrointestinal tract and abdominal cavity can be identified using ultrasonography. This article reviews the technique for abdominal ultrasonography, including its advantages and limitations, and provides an overview of necessary equipment. The ultrasonographic appearance of the gastrointestinal tract and peritoneum under normal and pathologic conditions is also described.

Gastrointestinal (GI) disorders represent a large proportion of the diseases encountered in equine medicine. Equine practitioners routinely evaluate horses with colic with the goal of early, accurate diagnosis. Even after a thorough examination, however, the exact cause of abdominal discomfort can be difficult to determine. This is partly due to the size of the abdominal cavity; only one third to one half of the abdominal volume can be examined by transrectal palpation in most horses.

Transabdominal ultrasonography, a safe, direct, and noninvasive diagnostic aid in evaluating colic patients, is routinely performed in many referral facilities. The technique is recommended not only for patients whose size prohibits transrectal palpation but also when additional information is required for accurate diagnosis of any patient. Useful information can be obtained with the standard equipment used by large animal practitioners.

EQUIPMENT

Sector and linear transducers both produce high-quality images for transcutaneous abdominal ultrasonography. Sector scanners produce pie-shaped images that provide a narrow near field of view and a wide far field of view. These transducers also have a small footprint (i.e., surface of contact) that facilitates intercostal imaging, particularly in a dorsal or longitudinal plane. Linear transducers produce a rectangular image that is well suited for examining superficial structures; however, with increasing depth the image of the far field is automatically narrowed, which restricts visualization of deep structures. Acoustic shadows will be produced by overlapping the ribs when imaging from an intercostal window in the dorsal or longitudinal plane with a linear transducer.

Curved linear transducers were developed to combine the desirable characteristics of sector and linear transducers. Curved linear transducers provide wide near and far fields of view, and the footprint size is usually intermediate. To avoid diagnostic errors and oversights, patients should ideally be evaluated with a transducer that is capable of resolving near- and far-field structures.

The depth at which structures can be observed varies with the frequency of the transducer. A 5-MHz transducer provides maximal penetration of approximately 10 cm, whereas a 3.5-MHz transducer can locate structures as deep as 22 cm from the skin. Because of the size of the equine abdomen and dimensions of the organs, a probe with a frequency of 3.5 MHz or lower may be required for evaluating the GI tract in adult horses. Ultrasound machines used in large animal practice are generally equipped with a 5-MHz linear-array transducer, which can be used to perform most of the studies described in this article. In adult horses (450 to 500 kg), however, a 5-MHz transducer does not allow complete evaluation of the abdomen. Although higher frequency probes can provide better image resolution, their penetration is less. A 7.5-MHz transducer can provide detailed images of structures closely associated with the abdominal wall.

Gain and power settings should be adjusted during the examination to obtain a homogenous image throughout the entire field being examined. When a suspicious structure is identified, the depth setting should be adjusted so that the entire structure is visualized in relation to a landmark (e.g., greater curvature of the stomach in relation to the splenic vein) or a specific portion of the structure is observed in detail (e.g., a portion of the gastric wall associated with a mass). More detailed descriptions of the various settings available in ultrasound machines and their effects are available in the literature.[1] Every suspicious area should be scanned repeatedly and at different angles to avoid interpreting artifacts as lesions. Ultrasound images should be labeled, recorded, and saved as part of the horse's medical record.

TECHNIQUE

Contact between the probe and horse can be improved by applying ultrasound coupling gel to the skin after clipping or shaving. Applying copious amounts of isopropyl alcohol with a sponge on a clean horse generally eliminates the air interface between the skin and transducer and provides satisfactory images where clipping is not performed. Care should be taken during the first application of alcohol because the cold sensation can surprise sensitive patients. Image quality is often inadequate in overweight or dehydrated horses; clipping the area of interest may improve visualization of the intraabdominal organs. Better contact between the horse and transducer improves visualization of subtle details that may be missed otherwise.

Foals can be examined while recumbent or standing. When scanning a recumbent animal, the transducer cannot be applied on the dependent parts of the abdomen; visualization of the pathologic segments of intestine may be prevented because heavier structures (e.g., thickened loops of intestine) often gravitate to the lowest portions of the abdomen. In addition, reflection caused by gas contained in the dorsal loops may preclude adequate visualization of the intraabdominal organs when recumbent foals are scanned. To calm the mare and minimize risk to equipment, foals should preferably be examined in front of mares, with the foal placed between the examiner and the mare. The mare can be sedated if necessary. Sick or hypothermic foals should be examined in a warm environment, with the conservative use of alcohol to prevent excessive heat loss.

It is important for examiners to adopt a safe, comfortable position because systematic screening of the entire abdomen may be time-consuming. Some ultrasonographic examinations of the abdomen, however, may be brief and directed at a specific area of suspicion.

GENERAL PRINCIPLES

Gas and mineralized structures appear as bright white (i.e., hyperechoic) areas and create acoustic shadowing, which prohibits visualization of underlying structures. This phenomenon results from the almost complete reflection of ultrasound waves at the level of a soft tissue–gas or soft tissue–bone interface.

Soft tissue–gas interfaces may also create an artifact called *reverberation*, which occurs when the wave front is scattered and delayed in returning to the transducer.[2] Reverberation is imaged as a series of parallel, echogenic lines underlying the soft tissue–gas interface. Fluid is generally black (i.e., anechoic), but can appear in shades of gray (i.e., hypoechoic) depending on its cellular or particulate content. The echogenicity of structures located deep to fluid is enhanced, and they appear brighter. This occurrence, called *acoustic enhancement*, results from a lack of attenuation of ultrasound waves traversing a fluid-filled structure. The brightness of the image produced is proportional to the loudness of the echo, which is directly related to differences in the densities of adjacent tissue and the depth from which the echoes came.[2] The reflection of echoes toward the transducer is maximal when ultrasound waves strike an interface between tissues of different densities at a 90° angle. When the angle of incidence is oblique, ultrasound waves are refracted and do not return toward the transducer, thereby diminishing the intensity of the returning beam. Images are displayed assuming that all echoes returning to the transducer have an angle of incidence of 90°. Refraction artifacts may therefore result in inaccuracy in the depth and density of the structures displayed. Refraction artifacts are commonly observed when scanning curved structures.

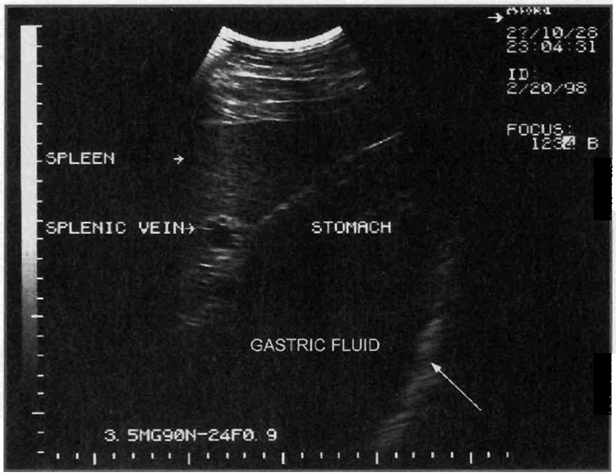

Figure 1—Gastric distention caused by anterior enteritis. The greater curvature of the stomach is medial to the splenic vein. Hypoechoic fluid is present within the lumen and separated from the dorsal gas cap by a fluid–gas interface (*long arrow*). This sonogram was obtained with a 3.5-MHz curved linear transducer positioned with the long axis in the left 12th intercostal space (dorsal is to the right and ventral to the left of the image).

ANATOMY

A thorough knowledge of topographic anatomy is necessary to accurately interpret ultrasound images. Experience gained by scanning normal horses helps examiners to become familiar with the size, position, and morphology of abdominal organs. This anatomic understanding enables practitioners to detect abnormalities potentially related to signs of colic.

ULTRASONOGRAPHIC EXAMINATION OF THE GASTROINTESTINAL TRACT

Stomach

In adult horses, the stomach can be visualized between the left 11th, 12th, and 13th intercostal spaces at shoulder level, depending on the degree of distention. The greater curvature of the stomach appears as a hyperechoic gas echo deep to the homogenous splenic parenchyma, and it curves toward the skin cranially; it is located on the medial or craniomedial aspect of the splenic hilus, in which the large splenic vein is observed. In cases of severe distention, the stomach is against the body wall, displacing the spleen caudally and ventrally (Figure 1). The distended stomach is generally characterized by the presence of a large, fluid-filled structure ventral to the lung margin.[3] In cases of severe gastric distention, visualization of the stomach may help to assess the efficacy of decompression by nasogastric intubation. If significant gastric distention is observed despite the absence of gastric reflux, further attempts should be made to obtain gastric fluid.

Gastric impactions may be suspected when the visible surface of the stomach extends over five or more intercostal spaces and hyperechoic material is present within the lumen.[4] Delayed gastric emptying may occur if a significant amount of gastric content is consistently observed in a fasted horse. Gastric squamous cell carcinoma generally involves the greater curvature of the stomach and is usually visualized as a mural mass of heterogenous echogenicity.[4] One report mentions increased thickness and decreased echogenicity of the gastric wall in a case of gastric squamous cell carcinoma.[5] Locally invasive carcinomas may cause a roughening of the serosal surface of adjacent organs or appear as masses that can reach several centimeters in size.[6]

Small Intestine

The only fixed portion of the small intestinal tract is the duodenum, which can be visualized on the right side of the abdomen along a line connecting the right olecranon to the tuber sacrale.[7] The duodenum courses caudally from the mid-abdomen between the 10th and 12th intercostal spaces medial to the right liver lobe to the 15th and 16th intercostal spaces underneath the body wall below the ventral aspect of the right kidney. Loops of small intestine can generally be visualized in the lower-left quadrant, medial to the spleen in adult horses; they appear as rounded or tubular structures, depending on the plane of ultrasonographic visualization. The diameter and shape of small intestinal loops, however, may vary with peristaltic movements. Complete loops can often be visualized due to the presence of fluid that allows deeper penetration of ultrasound waves. Segments of intestine can generally be observed gliding freely against other serosal surfaces. The walls are smooth, without bands or haustra on the outer surface. The thickness of the walls in a normal bowel is approximately 3 to 4 mm in the duodenum[7] and less than

3 mm in other portions of the small intestinal tract visualized by ultrasound.[8]

With high-resolution images, five layers may be distinguished within the intestinal wall: (1) a hyperechoic inner layer representing the boundary between luminal content and the mucosa, (2) a hypoechoic layer corresponding to the mucosa, (3) a hyperechoic layer corresponding to the submucosa, (4) a hypoechoic layer corresponding to the muscularis propria, and (5) an outer hyperechoic layer corresponding to the subserosa and serosa.[7] Depending on the degree of distention and type of ultrasound equipment used, fewer layers may be distinguished. In one report, the mucosa, submucosa, and muscularis were the most readily visualized.[7] Changes in the diameter of the small intestinal loops, motility, content, thickness of the walls, and location and number of loops may be observed in horses presenting with signs of colic.

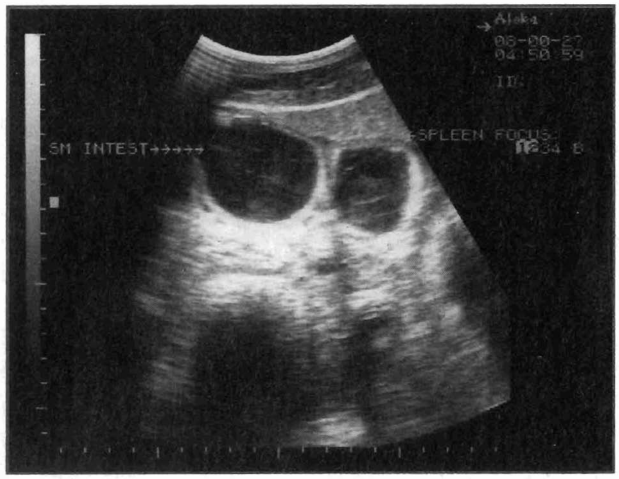

Figure 2—Small intestinal distention caused by an ileal impaction in a horse presented with colic of several hours duration. The small intestinal loops are turgid, the diameter is homogenous, and the thickness of the intestinal wall is normal; motility was absent. This sonogram was obtained by placing a 3.5-MHz curved linear transducer on the ventral aspect of the mid-abdominal region.

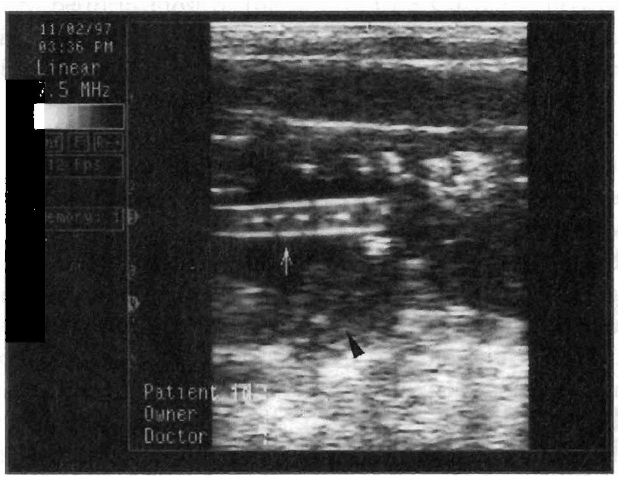

Figure 3—*Parascaris equorum (arrow)* in the small intestinal lumen of a 5-month-old foal. Note the increased thickness, decreased echogenicity, and corrugation of the intestinal wall *(arrowhead)* caused by diffuse necroulcerative enteritis. This sonogram was obtained with a 7.5-MHz linear transducer placed on the ventral abdomen.

Paralytic (Nonobstructive) Ileus

Paralytic ileus occurs when the neuromuscular function of the intestine is disturbed. It is characterized by decreased peristalsis, usually affecting the small intestine; secondary gastric distention may also occur. Nonobstructive ileus can cause significant distention of the small intestine, but the loops are generally not as tightly distended as in cases involving an obstruction. Ileus should be suspected when a segment of intestine presents little or no activity over a period of time.[6] Ileus caused by proximal enteritis results in various degrees of small intestinal distention, bowel wall thickness, and motility; differentiating this condition from other causes of ileus using ultrasonography may be difficult.

Mechanical (Obstructive) Ileus

Mechanical ileus occurs when the intestinal lumen is obstructed. Possible causes of obstructive ileus include simple obstructions, such as ileal impaction, intestinal stricture, ileal muscular hypertrophy, intestinal fibrosis, inflammatory (infiltrative) bowel disease, and ascarid impaction. Simple obstruction may also result from the presence of masses (intra- or extraluminal) or a foreign body (rare in the small intestine).

Strangulating obstructions constitute another cause of mechanical ileus and are characterized by an interruption in the intestinal blood supply. Possible causes include volvulus, pedunculated lipoma, incarceration of a portion of the small intestine, fibrous adhesion, hernia (inguinal, umbilical, or diaphragmatic), or intussusception.

Small intestinal loops proximal to an obstructive lesion become distended and appear round in cross-section. Motility is generally depressed; the loops often seem fixed without apparent contractions. Fluid content may swirl, but there is no significant peristalsis. The thickness of the walls varies depending on the cause of the distention. The number of loops observed with distention depends on the location of the obstruction and duration of the process.

In horses with simple obstruction (e.g., that caused by ileal impactions), the ventral abdomen may appear filled with distended loops of small intestine, depending on the duration and severity of the obstruction.

The distention is often marked with a similar diameter for all loops observed. The small intestinal walls are not thickened, and motility is markedly decreased or absent (Figure 2).

Both small intestinal obstruction caused by ascarids and simple obstruction of the duodenum due to stricture can occur in foals; the parasites may be identified (Figure 3) and the area of duodenal stricture visualized[9] using transabdominal ultrasonography. Visualization of a duodenal stricture may be facilitated by the presence of peritoneal fluid surrounding the duodenum. The fluid delineates the serosal surface of the duodenum and sometimes allows visualization of a fixed reduction of the duodenal diameter. Ileal muscular hypertrophy is characterized by a marked thickening of the muscular layer of the intestinal wall and may result in ileal rupture and diffuse peritonitis (Figure 4).

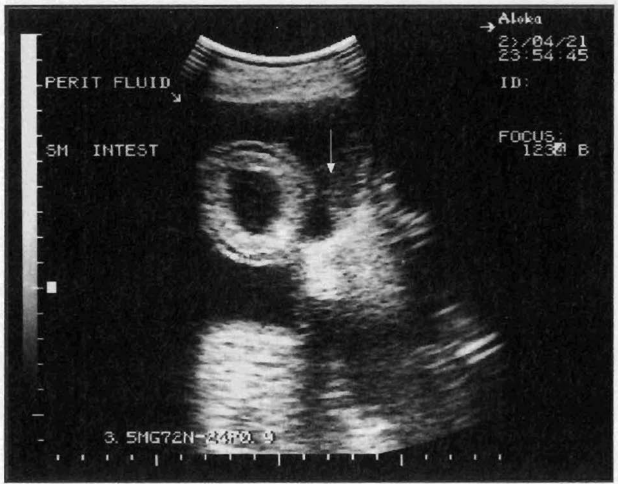

Figure 4—Ileal hypertrophy with edema of the mucosa and the muscular layer. The segment of small intestine viewed in short axis in this sonogram is distended by fluid content. Note the abundant peritoneal fluid of heterogeneous echogenicity containing hyperechoic particles (*arrow*) that is consistent with rupture of a viscus. This sonogram was obtained with a 3.5-MHz curved linear transducer placed in the left inguinal area.

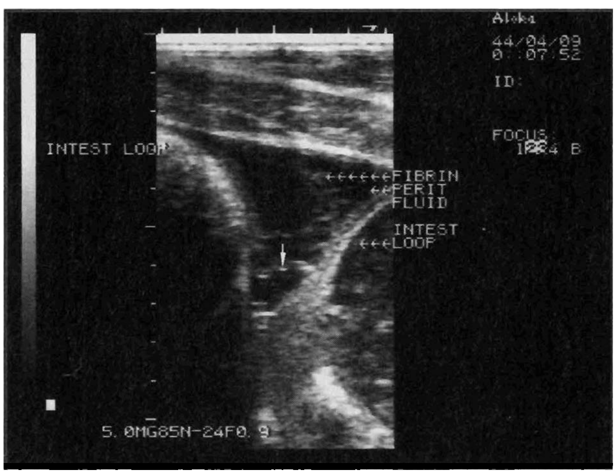

Figure 5—Peritonitis caused by intestinal perforation. Note the peritoneal effusion and fibrin tags on the intestinal serosa and peritoneum, causing a roughening of these surfaces. The peritoneal fluid is abundant and of heterogenous echogenicity. Hyperechoic particles in the peritoneal fluid (*arrow*) may be consistent with gas bubbles. This sonogram was obtained with a 5-MHz linear transducer placed slightly to the left of the ventral midline in the mid-abdominal area.

Intestinal wall thickening may also be caused by cellular infiltration, fibrosis, and chronic peritonitis. Infiltrative diseases of the small intestine generally result in chronic, low-grade colic; weight loss; or ill thrift and do not cause acute signs of abdominal pain or significant small intestinal distention. In cases of chronic peritonitis, fibrin deposition on the serosa may occur, but the resultant surface irregularity and peritoneal effusion generally make it easier to differentiate peritonitis from primary thickening of the wall (Figure 5).

Wall thickness is increased in only a few loops in cases of strangulating obstruction of the small intestine, whereas the thickness of the majority of distended small intestinal segments is normal. Mucosal edema of the strangulated segment leads to the increased wall thickness, which can be observed using ultrasonography. Mucosal edema generally has a less echoic appearance than does cellular infiltration of the intestinal wall, fibrosis, or hypertrophy of the wall.[9] Necrosis sometimes induces the production of a gas echo within the intestinal wall, and sloughing of the intestinal mucosa may be accompanied by the presence of an underlying anechoic fluid line. Strangulation of the small intestine generally affects intestinal motility; the presence of edematous small intestine associated with decreased motility justified surgical intervention in one study.[8]

In horses with epiploic foramen entrapment of the small intestine, transabdominal ultrasound may reveal amotile edematous loops in the right side of the abdomen. Ultrasound findings may indicate the need for surgical intervention before clinical signs of a strangulating lesion have become evident or when rectal findings are inconclusive.[10]

Intussusception of the small intestine appears as a "targetlike" lesion,[11] with the intussusceptum visible within the lumen of the intussuscipiens when scanned in a short axis. Varying degrees of intestinal wall edema are seen in both segments, and fluid and/or ingesta may be observed within one or both lumen. The combination of the two causes the target-shaped appearance created by concentric layers of different echogenicity. The small intestine segment proximal to the intussusception is generally fluid-distended with normal or nearly normal wall thickness and decreased motility.[11] Intussusceptions may involve any portion of the small intestine and occur more frequently in foals and young horses.

Diaphragmatic hernia characterized by the presence of loops of small intestine in the thoracic cavity can be diagnosed with ultrasonography (Figure 6). Loops of small intestine are visualized under the lung margin without separation of the intestinal structures and ventral lung border by the diaphragm. Ileus may or may not be present. The stomach or liver may rarely be displaced into the thoracic cavity. Diaphragmatic hernias may be accompanied by some degree of pleural/peritoneal effusion characterized by anechoic fluid below the lung margins and around the loops of intestine.

Cecum and Large Colon

The large colon occupies the ventral and cranial aspects of the abdomen and underlies the spleen, liver, and diaphragm in normal horses. The cecum is located on the right side, underneath the body wall, and courses cranioventrally from the right paralumbar fossa. Haustra appear as a series of rounded, hyperechoic lines. The wall of the colon and cecum generally appears thicker and rougher than that of the small intestine. In most cases, only the most superficial portion of the large colonic or cecal wall can be seen because of the presence of gas that prevents further penetration of ultrasound waves.

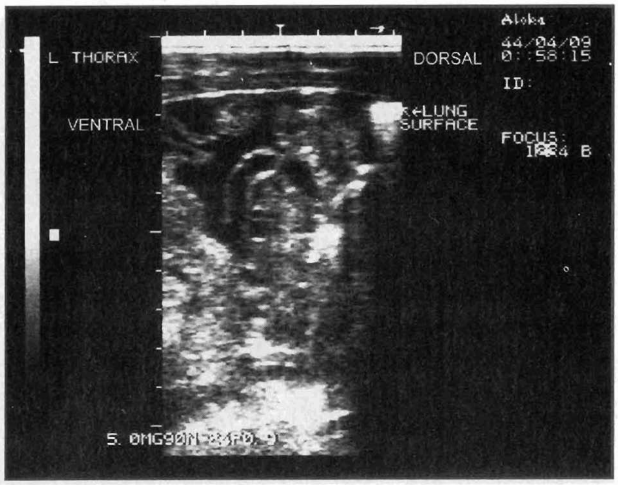

Figure 6—Diaphragmatic hernia characterized by the presence of several loops of small intestine below the ventral aspect of the lung surface and lack of visualization of the diaphragm. The mesentery is clearly visualized because of the presence of abundant hypoechoic fluid. This sonogram was obtained by placing the long axis of a 5-MHz linear transducer in the intercostal space (dorsal is to the right and ventral to the left of the image).

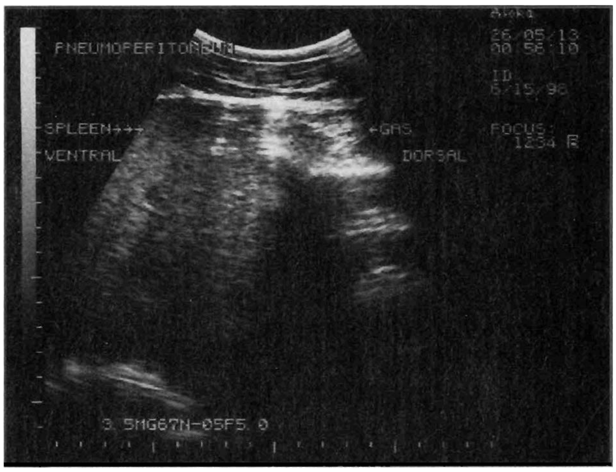

Figure 7—Pneumoperitoneum in a horse 48 hours after laparotomy. Reverberation artifacts are present dorsal to the spleen. The presence of gas in the dorsal aspect of the abdominal cavity was imaged in both sides. This sonogram was obtained with a 3.5-MHz curved linear transducer placed at midheight of the left flank.

Nephrosplenic Entrapment

Nephrosplenic entrapment of the large colon impairs visualization of the left kidney. The condition is characterized by a gas echo dorsal to the spleen in the left paralumbar fossa in a space delimited by the 17th intercostal space cranially, ventral lumbar muscles dorsally, and cranial thigh musculature caudally.[12] Nephrosplenic entrapment is often accompanied by ventral displacement of the spleen to the right of the ventral midline.

Ultrasonographic examination of the nephrosplenic space can be used in conjunction with rectal palpation to assess the progress made in attempts to correct the displacement by rolling the horse. However, examiners should be cautious in their interpretation of the presence of a gas echo dorsal to the spleen; the small colon or small intestine is sometimes visualized between the spleen and the left kidney, and this is generally an incidental finding not related to colic. Pneumoperitoneum may also create a gas interface in the dorsal aspects of the peritoneal cavity (Figure 7). Ultrasonography should be used in combination with other parameters (e.g., history, clinical signs, rectal palpation) to support the diagnosis of nephrosplenic entrapment of the large colon.

Colonic Impaction

Sand impaction of the large colon is often suspected in cases of chronic colic or diarrhea based on history and geographic location. Definitive diagnosis, however, is sometimes difficult to obtain. Ultrasonography may provide a useful complement to other examinations to confirm the presence of sand and may help practitioners follow the condition's progress. When present in large amounts in the large intestine, sand is frequently seen on the ventral aspect of the abdomen. A band of variable thickness and homogenous echogenicity with a somewhat glittery appearance can be visualized under the brighter limit of the large intestine. When the dorsal layers can be visualized, a slow, horizontal motion can sometimes be observed.

Ultrasonography can be used in foals to support the diagnosis of meconium impaction in the large colon or, more frequently, the terminal portion of the small colon dorsal to the bladder. Meconium impactions have soft-tissue echogenicity.[9] Hypoechoic or echogenic masses of meconium in the large intestine are often surrounded by fluid.[13]

Intussusception

Intussusceptions are observed less frequently in the large colon and cecum than in the small intestine. Ultrasonography may be helpful in diagnosing ileocecal and cecocolic intussusceptions (Figure 8).[14] If the intussusceptum is surrounded by fluid, the two segments may be observed clearly. Intussusceptums are often markedly thickened from edema and necrosis. If gas is present, the deep wall of the intussuscipiens may not be apparent.

Figure 8—Cecocolic intussusception characterized by the presence of an edematous segment of the cecum separated from the body wall by a layer of normal large intestinal wall (intussusceptum, *arrow*; intussuscipiens, *arrowhead*). The deep wall of the intussusceptum is not visible in this image. The large intestine can be recognized by the presence of haustra. This sonogram was obtained by placing a 3.5-MHz curved linear transducer in the caudoventral portion of the abdomen to the right of the ventral midline.

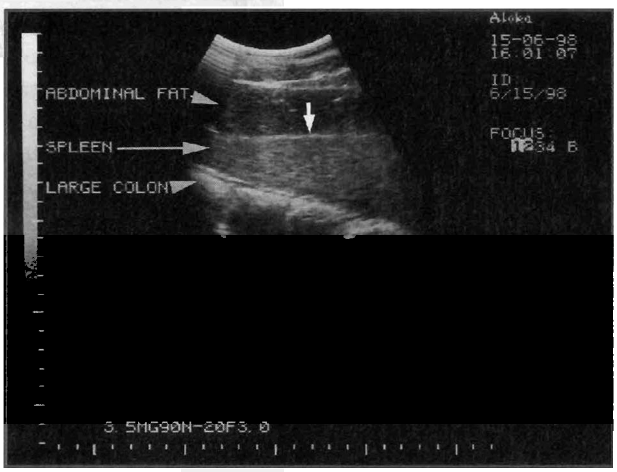

Figure 9—Abdominal fat characterized by the presence of a hypoechoic layer with hyperechoic "sparkles" underlying the parietal peritoneum (*arrow*). This sonogram was obtained with a 3.5-MHz curved linear transducer placed on the ventral abdomen.

Colitis

Horses with impending or existing colitis may present with signs of abdominal discomfort and shock. In these cases, transabdominal ultrasonography generally reveals a fluid-filled large colon and cecum. There may be an increase or decrease in intestinal motility, and the fluid content may be static or rapidly swirling within the lumen.

Peritoneum and Peritoneal Fluid

Gastrointestinal disorders responsible for colic may be accompanied by an integrity loss in the intestinal barrier, leading to changes in the peritoneum and peritoneal fluid. Characterization of the peritoneal fluid using ultrasound may help to determine the prognosis more accurately or to locate an area where abdominocentesis should be performed. Parameters to be evaluated include quantity, echogenicity, motion, and the presence of solid particles or gas echoes. In normal horses, only a small amount of anechoic fluid should be present between intraabdominal organs or underlying the abdominal wall. Abdominal fat is found between the muscular layers of the body wall and the parietal peritoneum, appearing as a homogenous, hypoechoic layer containing brighter "sparkles," and is relatively fixed in its relationship to the abdominal wall (Figure 9). Abdominal fat should not be mistaken for peritoneal fluid.

Large amounts of anechoic fluid without particles may be consistent with transudate, early exudate, or uroperitoneum. In the presence of large amounts of fluid, loops of intestine and intraabdominal organs appear separated from one another and "lifted' from the ventral aspect of the abdomen. The echogenicity of the fluid increases with the cellular content. Exudate is more echogenic

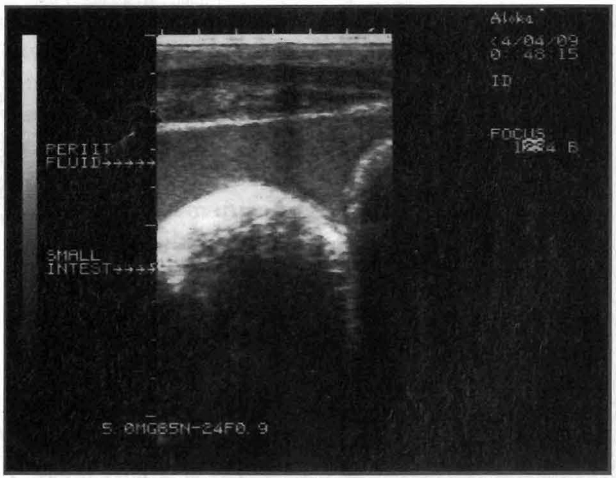

Figure 10—Exudate characterized by the presence of highly cellular fluid bathing the viscera in a horse with septic peritonitis caused by intestinal perforation. This sonogram was obtained with a 5.0-MHz curved linear transducer placed on the ventral abdomen.

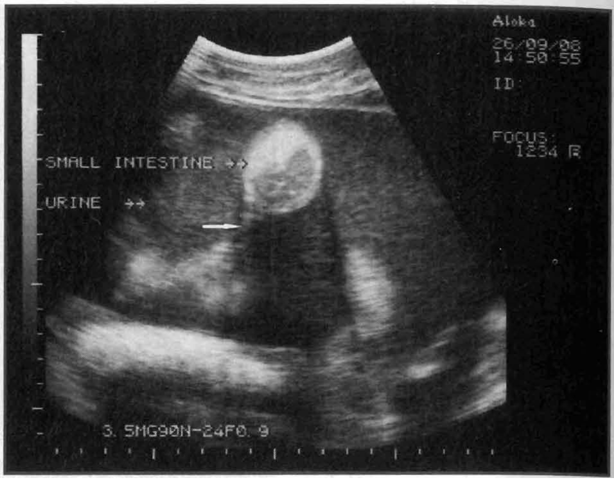

Figure 11—Uroperitoneum associated with ruptured bladder in a postpartum mare. Note the presence of a loop of small intestine casting an acoustic shadow. Mesentery (*arrow*) is also visible in this sonogram, which was obtained with a 3.5-MHz curved linear transducer placed on the ventral abdomen.

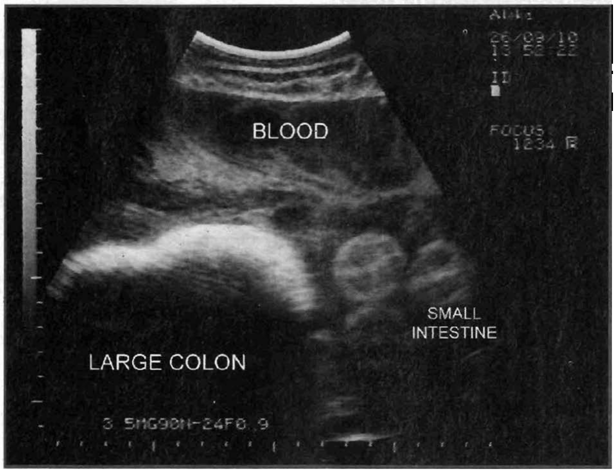

Figure 12—Hemoperitoneum caused by hemorrhage in a mare with a history of recent trauma in the left flank. Note the swirling hyperechoic material caused by hemorrhage in this case. This sonogram was obtained with a 3.5-MHz curved linear transducer placed on the ventral abdomen.

than is transudate or urine and appears as a layer of fine, particulate, homogenous material bathing the viscera (Figure 10). Urine in adult horses appears as an anechoic fluid, but because of the high content of calcium-carbonate crystals and mucus, the appearance of uroperitoneum may vary from anechoic to hypoechoic (Figure 11). The site of bladder rupture may sometimes be visualized in foals using transabdominal ultrasound, but transrectal examination is necessary in adult horses. Diagnosis of uroperitoneum may be confirmed by analyzing the fluid collected via abdominocentesis. In acute abdominal hemorrhage, blood appears echogenic. If intraabdominal bleeding is severe, such as in some cases of uterine artery or splenic rupture, a swirling motion can be observed (Figure 12). Within hours, clots appearing as masses of heterogenous echogenicity may be formed.

Particles observed floating freely in the peritoneal fluid or attached to viscera may consist of ingesta or fibrin. Viscus rupture is often accompanied by the presence of abundant fluid that appears hypoechoic and contains hyperechoic ingesta. Gas bubbles forming small, bright sparkles floating in the abdominal fluid (Figure 5) are frequently seen in cases of ruptured viscus.

The serosal surfaces of the abdominal organs and parietal peritoneum may present with abnormalities. Deposition of fibrin results in an increased thickness of the peritoneal lining (Figure 5). Fibrin usually forms "tags" that appear as strands connected to viscera or the parietal peritoneum. Fibrin is frequently observed in cases of chronic peritonitis, but it may form within a few hours in severe cases of intestinal damage. Metastases originating from intraabdominal neoplasia may occasionally cover the peritoneum, creating a granulomatous, irregular appearance. Adhesions between serosal surfaces may be suspected if a portion of the intestinal tract is repeatedly observed in the same location and no movement independent from adjacent serosal surfaces is present. Fibrin tags connecting loops of intestine can sometimes be visualized and may also be located between intestinal loops and peritoneum or other intraabdominal organs. Care should be taken not to interpret normal structures (e.g., mesentery) as fibrin. If a significant amount of effusion is present within the abdominal cavity, the mesentery may be delineated by fluid and appear as a bright, linear echo attached to a loop of small intestine (Figure 6).

Pneumoperitoneum is generally associated with bowel rupture or recent laparotomy. Free gas in the abdomen may occasionally be imaged as a hyperechoic area underlying the body wall in the dorsal abdomen. Reverberation artifacts may also be present (Figure 12). Pneumoperitoneum should not be confused with the presence of gas within the large colon or cecum. Confirming pneumoperitoneum may require radiography of the craniodorsal aspect of the peritoneal cavity to identify the presence of air outlining the peritoneal surface of the diaphragm or kidneys.

DIAGNOSING NONGASTROINTESTINAL CAUSES OF COLIC

Reproductive Tract

Mares in late gestation may experience some discomfort because of the space the uterus occupies and the subsequent compression of, or tension on, intraabdominal structures. If transrectal palpation is not effective during advanced pregnancy, abdominal ultrasonography can be used to evaluate the uterine environment and fetal well-being and rule out GI causes of colic. Abnormalities related to the fetal membranes (e.g., hydrops) can also be diagnosed by ultrasonography.[15] Ovarian tumors may become quite large and cause a mechanical compression and/or obstruction of some portions of the intestinal tract, resulting in colic.

COMPENDIUM'S 20th ANNIVERSARY

A Look Back

Ultrasonography has become an integral part of equine medicine in the past 20 years. Because of recent advances in technology, high-quality ultrasound equipment is now available in private practices. Investment in this type of equipment is justified considering the tremendous diagnostic potential it offers at a reasonable cost. Much progress has been made since information on the use of ultrasonography in equine practice was first published 30 years ago. Equine practitioners should now be aware of the many potential applications of this technology in equine medicine, including its use in the diagnosis of colic.

Urinary Tract

Abdominal distention caused by uroperitoneum in cases of bladder rupture may cause mild colic in foals and, less commonly, adult horses.[16] Nephrolithiasis and ureteral calculi may be associated with mild discomfort. Renal ultrasonography may help clinicians confirm the presence of calculi.

Liver and Biliary Tract

Cholelithiasis is commonly associated with recurrent abdominal discomfort, icterus, and intermittent fever.[17–19] Ultrasonography of the liver is frequently used to diagnose cholelithiasis.

Nondigestive Organ Masses

Masses within the abdominal cavity may cause signs of abdominal discomfort. Intraabdominal abscesses, hematomas, or neoplastic masses can occasionally be diagnosed using transabdominal ultrasonography. Abscesses often have a loculated appearance and may involve a portion of intestinal wall.[4] A hyperechoic capsule may be present and, in some cases, air–fluid interfaces are observed, causing an acoustic shadow within the mass. Neoplastic and granulomatous masses vary from hypoechoic to hyperechoic in appearance with different degrees of homogeneity in echogenicity. Abdominal tumors may involve various organs, lymph nodes, and vessels. Metastases frequently occur in horses with abdominal neoplasms, and ultrasonography may reveal their presence in various organs or on the peritoneum.

CONCLUSION

Transabdominal ultrasonography is a useful complement to the traditional examination of colic patients. It is a safe, noninvasive tool that greatly enhances the diagnostic ability of practitioners. Transabdominal ultrasonography is strongly recommended in young animals or small horses in which rectal palpation cannot be performed safely. Care should be taken, however, not to rely strictly on ultrasound images to establish a diagnosis. Artifacts are common and may be misleading. Any information obtained during ultrasonographic examination must be correlated to other clinical parameters. The experience necessary to interpret images accurately can be acquired by scanning normal horses before examining patients with abdominal crisis. The systematic use of abdominal ultrasonography in cases of colic helps practitioners become familiar with some of the changes induced in the intraabdominal environment. It may also help to determine the correct therapy early in the disease process, thereby improving the prognosis for correcting the condition.

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ARTICLE #5 CE TEST

1. Transabdominal ultrasonographic examination of horses with GI disorders
   a. must be performed in referral clinics equipped with high-quality ultrasound machines.
   b. often provides an accurate and definitive diagnosis.
   c. provides a useful complement of information to traditional examination of patients with colic.
   d. is recommended in foals and small horses in which transrectal examination is unsafe.
   e. c and d

2. Which of the following statements regarding ultrasound transducers is true?
   a. Only sector scanners can be used for evaluation of GI disorders in horses.
   b. Sector scanners provide a wider window of observation of superficial structures than do linear-array transducers.
   c. A linear-array transducer does not provide any useful information when used for transabdominal ultrasonography.
   d. A large linear footprint provides a wide window of observation in all planes when scanning intraabdominal structures from the intercostal spaces.
   e. Sector and curved linear transducers provide pie-shaped images.

3. Which of the following statements regarding transducer frequency is true?
   a. Frequency determines the depth of penetration of ultrasound waves.
   b. Frequency does not influence image resolution.
   c. A transducer with a frequency of 3.5 MHz or lower is always necessary to examine intraabdominal structures in horses.
   d. Deep structures are better viewed with a 5-MHz trans-

ducer than with a 3.5-MHz transducer.
   e. Horses with a thick body wall or abundant peritoneal fat require a 7.5-MHz transducer for transabdominal examination of the GI tract.

4. Patient preparation for transabdominal ultrasonography requires
   a. systematic clipping and shaving of the area to be examined.
   b. sedation because this procedure is generally not well tolerated by horses.
   c. general anesthesia in foals.
   d. lateral recumbency in foals.
   e. only copious application of isopropyl alcohol if the hair is short and clean.

5. General principles of ultrasonography imply that
   a. fluid is always black on ultrasound images.
   b. areas located deep to a fluid structure appear darker than does the surrounding tissue because of acoustic shadowing.
   c. gas or bone enhances the echogenicity of the structures located deep to it.
   d. lower-density tissue with high fluid content appears brighter than does higher-density tissue that contains little fluid.
   e. gas and bone appear as bright, hyperechoic structures.

6. When visualized by transabdominal ultrasonography, the stomach
   a. is best visualized from the right side of the thorax.
   b. is located medial to the splenic vein.
   c. is generally filled with fluid.
   d. may displace the spleen ventrally and caudally in cases of severe distention.
   e. b and d

7. When visualized by transabdominal ultrasonography, the small intestine
   a. is generally seen in the cranial portions of the ventral abdomen.
   b. is filled with gas, which prevents visualization of complete loops.
   c. has a wall thickness of approximately 2 mm.
   d. has a fixed diameter throughout its entire length.
   e. is always observed in the same location (except for the duodenum).

8. Which of the following statements regarding examination of small intestinal pathologies using transabdominal ultrasonography is false?
   a. Small intestinal distention associated with obstruction appears as rounded, fluid-filled structures closely apposed to each other.
   b. Infiltrative disease of the intestinal wall generally appears less echoic than does mucosal wall edema.
   c. Intussusceptions appear as target-shaped lesions when viewed in short axis.
   d. Apparent thickening of the intestinal wall may be caused by peritonitis.
   e. Diagnosis of diaphragmatic hernia may be supported by the presence of loops of intestine within the thoracic cavity (underlying the ventral margin of the lung).

9. Transabdominal ultrasonography of the large colon
   a. generally provides an image of the entire lumen and both the near and far walls due to the transmission of ultrasound waves by fluid content.
   b. always allows accurate diagnosis of nephrosplenic entrapment.
   c. allows accurate diagnosis of colon torsion.
   d. helps to determine if abdominal discomfort is associated with impending colitis.
   e. is not helpful in horses with acute abdominal pain.

10. Which of the following statements regarding examination of peritoneum and peritoneal fluid using transabdominal ultrasound is true?
   a. Peritoneal fluid cannot be observed in most normal horses.
   b. A large amount of dark peritoneal fluid containing multiple particles and gas "bubbles" is consistent with an exudate.
   c. Peritoneal fat can sometimes be mistaken for peritoneal fluid because of its dark appearance and hyperechoic "sparkles."
   d. When visualized by ultrasound, blood is less echoic than is urine.

March CE tests #6 through #9 accompany articles that are published in *Food Animal Medicine & Management (FAM&M)*, the supplement to *Compendium* that deals solely with food animal issues. *Compendium* readers who practice exclusively small animal and/or exotic animal medicine do not receive *FAM&M* and so do not have access to CE articles #6 through #9. CE tests #8 and #9 have been included here due to space constraints this month in *FAM&M*. CE tests #6 and #7 can be found with their respective articles in *FAM&M*.