Compendium

Understanding Abdominal Ultrasonography in Horses: Which Way Is Up?

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Abstract: *The recent introduction of more affordable and portable ultrasound equipment makes it possible to perform transabdominal ultrasonography on equine patients in the field. Clipping the hair is not always necessary: intraabdominal structures can be quickly evaluated by soaking hair with isopropyl alcohol and using a 3.0- to 3.5-MHz curvilinear transducer. The ultrasonographer must be acquainted with the location and architecture of normal intraabdominal structures and simultaneously mindful of the depth of the viewing field, the tissue interface densities, the orientation of the transducer relative to the patient, and the image projected on the monitor. A clinician's working knowledge of these elements is the key to building confidence in distinguishing normal from abnormal ultrasonographic findings.*

Although several different types of ultrasound transducers exist, adult equine abdomens are most often imaged using a 2- to 5-MHz curvilinear array transducer.[1] With the curvilinear transducer, ultrasound waves radiate from a curved footprint at the point of contact on the patient and generate a curved pie-shaped image through the plane of projection into the horse (**FIGURE 1A**, **FIGURE 1B**, **FIGURE 1C**). Likewise, low-frequency sector scanner transducers produce a pie-shaped image and penetrate sufficiently to enable visualization of deep structures. The smaller footprint of sector scanners fits well between ribs, making rotation of the probe less cumbersome than with other types of transducers. A high-frequency linear (6 to 8.5 MHz) or microconvex linear array transducer can be used to optimize resolution of superficial intraabdominal structures. Ideally, before ultrasonography, the patient's hair should be clipped with a #40 blade and the skin cleaned with water or isopropyl alcohol. Coupling gel should be applied liberally to the imaging area. If clipping the hair is not an option, removing haircoat debris with grooming aides and soaking the hair with isopropyl alcohol often suffice.

Many horses tolerate transabdominal ultrasonography without sedation. If sedation is needed, it should be remembered that α_2 agonists such as xylazine and detomidine induce a transient state of ileus; therefore, in sedated patients, intestinal motility may be reduced and the luminal diameter of the small intestine may appear more dilated than in unsedated patients.[2,3]

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Orientation of the Probe

Ultrasound transducers have a physical marker on them that provides orientation of the transducer's placement on the patient relative to the projected image on the viewing monitor. Because abdominal ultrasonography is often performed with the footprint of the transducer in an intercostal space, most imaging of the abdomen is performed with the transducer oriented in a slightly oblique transverse plane image (slicing across the long axis of the body), with the probe marker "up"—toward the dorsal aspect of the patient (**FIGURE 1A**). The probe position marker is displayed on the monitor, alongside the captured image, to orient the ultrasonographer to the displayed image relative to the patient (**FIGURE 1B**). For example, if the orientation marker on the transducer is dorsal (relative to the patient) to obtain a transverse plane and if the ultrasound

Key Elements That Can Assist With Understanding Ultrasonography

- Being aware of the orientation of the ultrasound probe relative to the patient
- Using information on the depth of the viewing field
- Understanding how the image is generated by the ultrasound machine
- Knowing the normal anatomy relative to placement of the ultrasound probe

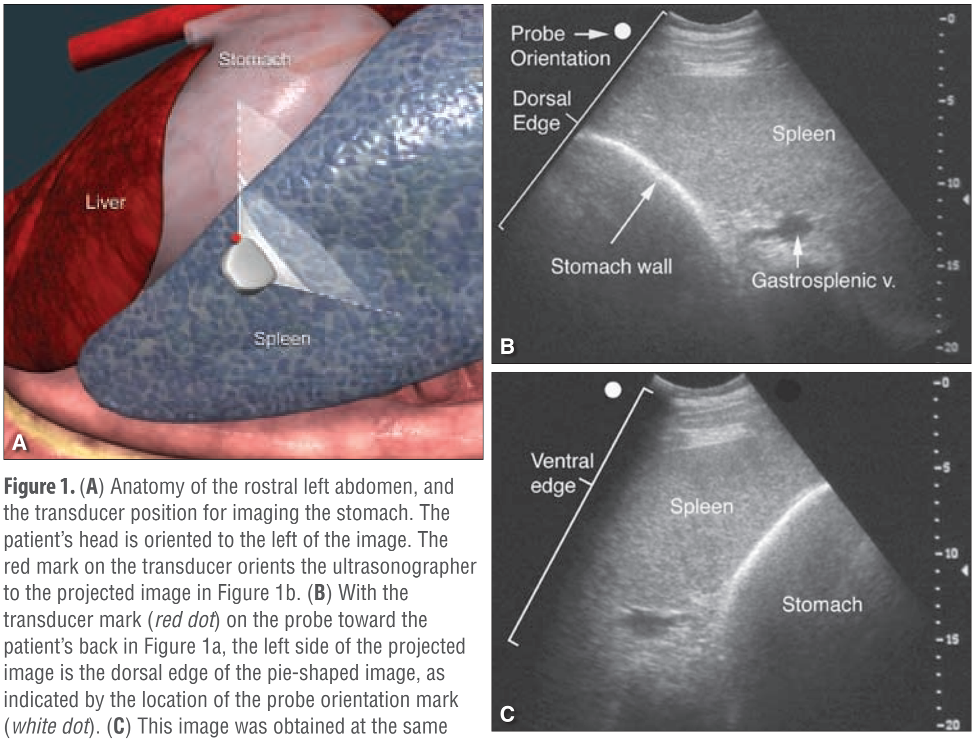


Figure 1. (**A**) Anatomy of the rostral left abdomen, and the transducer position for imaging the stomach. The patient's head is oriented to the left of the image. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 1b. (**B**) With the transducer mark (*red dot*) on the probe toward the patient's back in Figure 1a, the left side of the projected image is the dorsal edge of the pie-shaped image, as indicated by the location of the probe orientation mark (*white dot*). (**C**) This image was obtained at the same location as Figures 1a and 1b; however, the ultrasonographer has rotated the transducer 180°. With the transducer marker located ventrally on the patient, this image indicates that, relative to the white dot on the image, the ventral edge is to the left. The projected image is a vertical mirror image of Figure 1b. *Courtesy of The University of Georgia Glass Horse Project.*

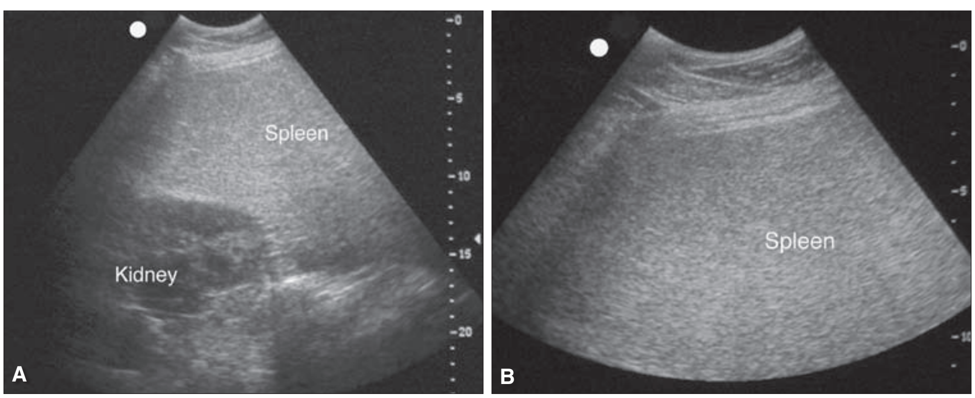


Figure 2. (**A**) This image of the left kidney and the spleen was obtained from the left caudal abdomen (Figure 6a) using a 3.5-MHz transducer projected to a depth of 24 cm (scale to the right of the image). The kidney is seen deep to the spleen. (**B**) This image of the spleen was obtained from the same location as Figure 2a; however, the depth of view is reduced to 11 cm, so the kidney is no longer visible. *Courtesy of The University of Georgia Glass Horse Project.*

machine normally displays the orientation mark in the upper left corner of the displayed image, the ultrasonographer immediately knows that the left side of the on-screen image represents the dorsal aspect (**FIGURE 1B**). Although the transducer works perfectly well if it is flipped 180° in the transverse plane on the patient, the left side of the projected image on the monitor will represent the ventral aspect of that slice, and the part of the image that previously appeared on the left side of the image (**FIGURE 1B**) will appear on the right side, representing the dorsal edge (**FIGURE 1C**). Therefore, it is imperative to have a consistent system for performing an ultrasonographic examination. Knowing the orientation of the transducer marker relative to the patient and the way the ultrasound machine normally displays its image greatly facilitates orientation to the structures on the monitor. The image display can be manually "flipped" on most ultrasound machines by pressing a left/right or top/bottom inversion key. Despite how the image displays on screen, the probe orientation marker on the monitor lines up with the same edge or side of the probe relative to its placement and orientation on the patient.

Depth of View

In any ultrasonographic examination, it is important to be mindful of the depth of the field of view. Selecting the appropriate frequency for the transducer is the key to producing high-quality images that are suitable for the depth of display. High-frequency probes provide sharp images, but the resolution is compromised as the depth of the viewing field increases. If a fixed, single-frequency probe is used, a 3.0- or 3.5-MHz curvilinear probe is the most suitable for imaging most of the abdominal viscera.[4] Orientation to the depth of view is easily accomplished by looking at the centimeter scale on the displayed image (**FIGURE 2A**). It is easy to think that something is missing from the field of view when the depth setting is too shallow to identify the structure of interest (**FIGURE 2B**). It is also easy to think that a structure or lesion is large when the depth of view is set to a few centimeters, which causes the image to appear large on screen.[5] Many ultrasound machines can penetrate to a viewing depth of 30 cm.

How an Image Is Generated

As ultrasound waves project through the body, they are reflected by tissue interfaces and sensed as "echoes." If adjacent tissues have the same acoustic impedance, no sound is reflected and sound waves penetrate into the deeper tissues, such as with layers of muscle. While denser tissues have greater acoustic impedance, the interface between adjacent tissues or tissues within the same

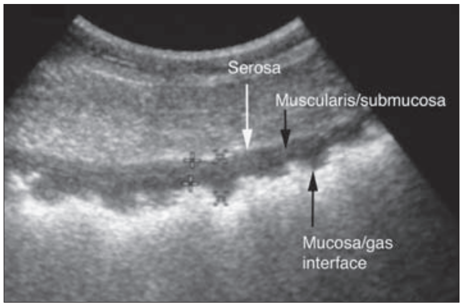


Figure 3. This image shows the most commonly identifiable layers (i.e., serosa, muscularis/submucosa, mucosa–gas interface) of the wall of the left ventral colon. The colon wall is edematous, accentuating the middle hypoechoic areas of the muscularis to the mucosa. This image was obtained with a 3-MHz curvilinear probe displayed to a depth of approximately 6 cm. *Courtesy of The University of Georgia Glass Horse Project.*

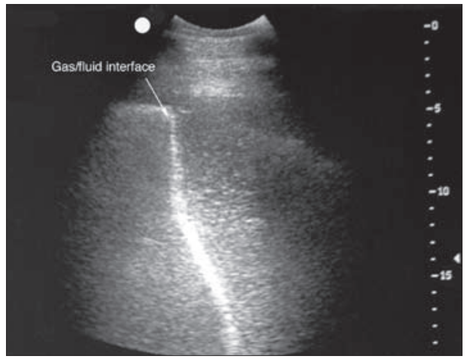


Figure 4. This image was obtained from the transducer position shown in Figure 1a. There is mild gastric distention, and a gas (dorsal to the left)/fluid (ventral to the right) interface is visible as the hyperechoic line between these areas of different acoustic densities. *Courtesy of The University of Georgia Glass Horse Project.*

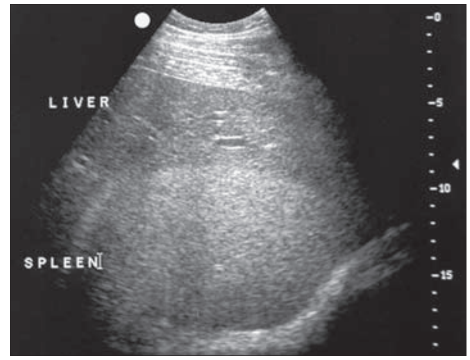


Figure 5. This image was obtained in the lower rostral left abdomen, where, in some horses, a small section of the left side of the liver can be seen adjacent to the spleen (Figure 1a). Note the contrast in echogenicity between the liver and spleen; the spleen is usually more echogenic. *Courtesy of The University of Georgia Glass Horse Project.*

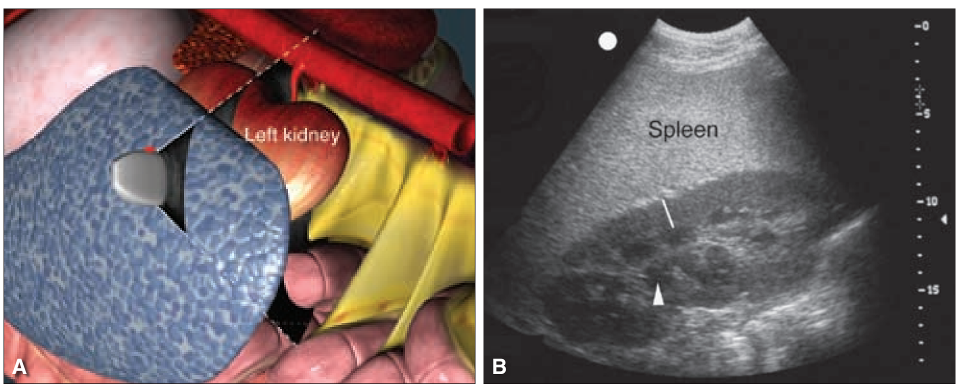


Figure 6. (**A**) Anatomy of the caudal dorsal left abdomen, and the transducer position for imaging the left kidney. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 6b. (**B**) The image from the transducer position in Figure 6a. The renal cortex (*line*) is more echogenic than the medulla. The hypoechoic medulla of the renal pyramids (*arrowhead*) often resemble hypoechoic circles. *Courtesy of The University of Georgia Glass Horse Project.*

organ determines how much of the sound wave reflects to the transducer.[1] The more sound reflects to the transducer, the "whiter" the image appears on screen; these tissue interfaces are called *echogenic* or *hyperechoic*. In contrast, less dense tissues reflect less sound, appear darker, and are called *anechoic* or *hypoechoic*. If the difference in tissue interface is primarily responsible for reflecting sound to the transducer, more sound waves should reflect to the transducer if two adjacent interfaces have markedly different acoustic impedances. The interface between soft tissues and gas is an excellent example of this concept. The soft tissue of the gastrointestinal (GI) walls has an acoustic impedance that is several thousand-fold greater than that of the free gas inside the adjacent lumen.[1] Consequently, the image at this soft tissue–gas interface appears as a fuzzy hyperechoic border (the stomach wall in **FIGURE 1B**). Because most of the sound waves at this interface are reflected and the free gas in the lumen has extremely low impedance, the rest of the lumen appears darker as sound is neither penetrating nor reflecting from the lumen. Gas within a large viscus is one of the greatest limitations to GI ultrasonography, especially in horses, which have a large GI tract. The gas prevents visualization of deeper structures. While imaging a patient, the ultrasonographer should remember that (1) fluid and heavier structures fall to the dependent side and (2) gas floats to the nondependent side and obstructs deeper views.

If juxtaposed to the abdominal wall, a high-resolution (7.5 to 10 MHz) linear array transducer on a thin patient may be able to image up to five layers to the GI wall: serosa (hyperechoic), muscularis (hypoechoic), submucosa (hyperechoic), mucosa (hypoechoic), and the mucosa–lumen interface (hyperechoic).[4] However, when the standard approach with a 3.0- to 3.5-MHz transducer is used, depending on the surrounding tissue and the contents of the lumen, only three or fewer layers are usually visible: hyperechoic serosa, the hypoechoic muscularis to the mucosa, and the hyperechoic interface with the lumen (**FIGURE 3**).

Integrating Knowledge of Normal Abdominal Anatomy

When the equine abdomen is scanned, it is important to use a systematic approach, scanning the left and right sides dorsally to ventrally and then rostrally to caudally. Careful attention should be paid to the spatial relationship of the viscera because this may be the key to distinguishing normal from abnormal findings.[5] The walls of some sections of the GI tract appear strikingly similar and may not be distinguishable if the clinician does not know where the transducer is placed on the abdomen.[6] Transabdominal ultrasonography provides not only structural information but also functional information (i.e., motility). Heavy sedation can cause

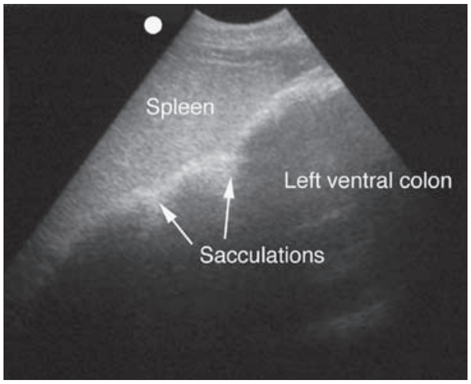


Figure 7. This image was obtained in the left flank of the left ventral colon, medial to, and at the ventral edge of, the spleen. The dorsal edge of the image is to the left. Note the sacculations of the left ventral colon. *Courtesy of The University of Georgia Glass Horse Project.*

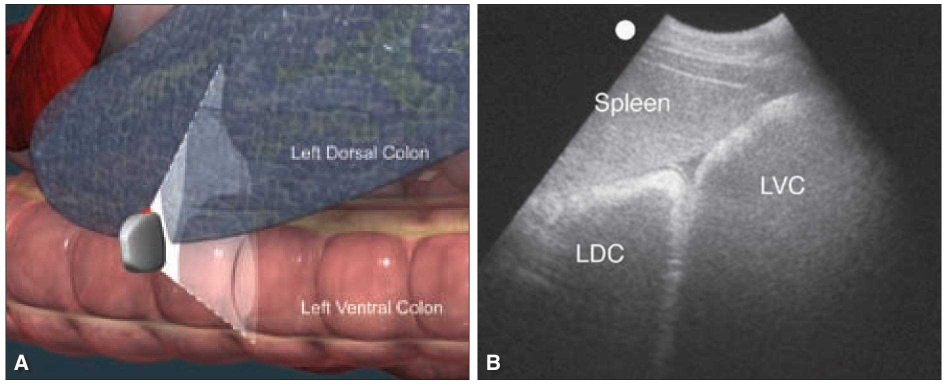


Figure 8. (**A**) Anatomy of the ventral left abdomen, and the transducer position for imaging the left colon. The patient's head is oriented to the left of the image. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 8b. (**B**) The image from the transducer positioned in Figure 8a. The dorsal edge of the image is to the left. *LDC* = left dorsal colon; *LVC* = left ventral colon. *Courtesy of The University of Georgia Glass Horse Project.*

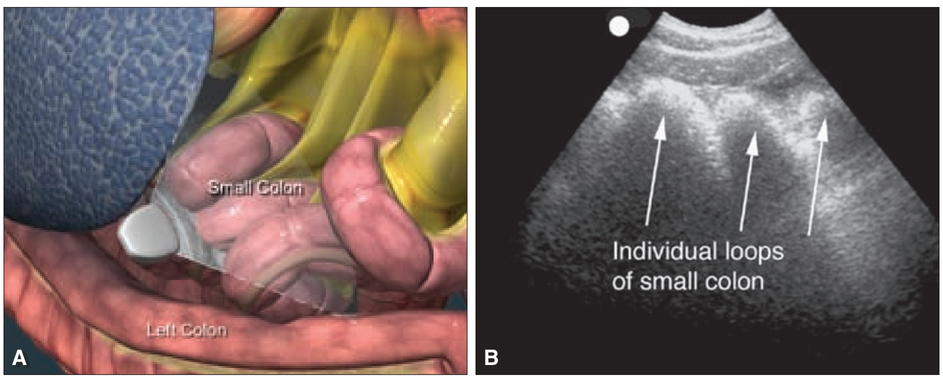


Figure 9. (**A**) Anatomy of the left paralumbar fossa for imaging the small colon. (**B**) The image from the transducer positioned in Figure 9a. The small colon often appears as short segments of curved hyperechoic lines. *Courtesy of The University of Georgia Glass Horse Project.*

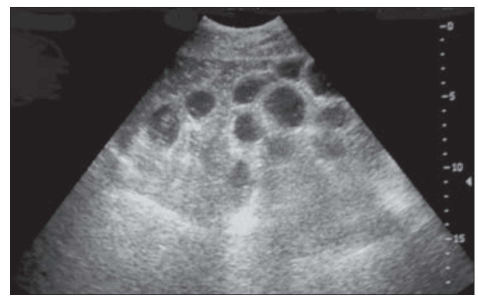


Figure 10. This image was obtained medial to the left colon in the left inguinal area and shows several loops of fluid-filled jejunum. Typically, the small diameter and fluid contents of the small intestine allow the entire circumference of the wall to be identified. *Courtesy of The University of Georgia Glass Horse Project.*

transient ileus and mild dilation of the small intestine.[3] Normal ultrasonographic anatomy is discussed below, starting from the left cranial abdomen and moving caudad, and then likewise on the right side.

Ultrasonographic Anatomy of the Left Side of the Abdomen

When imaging is started on the left rostral side of the abdomen, the stomach should be located deep to the spleen between the ninth and 13th intercostal spaces at approximately the level of the shoulder (**FIGURE 1A**). In this location, the only part of the stomach that can usually be seen is the wall of the greater curvature, which can be reliably identified as a curved hyperechoic line adjacent to the spleen and the gastrosplenic vein[7] (**FIGURE 1B**). If the stomach extends beyond the 14th intercostal space in a horse that has not recently eaten, gastric distention may be present. The stomach has the thickest wall in the GI tract, measuring approximately 7 mm thick from the serosal to the mucosal/lumen interface. When the stomach is empty, the wall may be up to 1 cm thick. Because only the dorsal portion of the greater curvature can be seen and the lumen generally contains gas in this location, the contents of the stomach are often not visible. If gastric fluid is present ventrally, a distinct gas–fluid interface may be apparent in the lumen (**FIGURE 4**).

Caudad from the stomach, the **spleen** should be identifiable immediately adjacent to the body wall, from the left ventral eighth intercostal space to the paralumbar fossa. The size and location of the spleen vary greatly: the spleen may be left of the midline or extend slightly right of the ventral midline. The only consistent measurement of the spleen is the central thickness (depth), which is usually <15 cm.[5] In the rostral ventral left abdomen of some horses, the most rostral aspect of the spleen can be seen either lateral or medial to the liver.[5] The spleen's ultrasonographic architecture is usually homogenous, with vessels that are rarely visible. The echogenicity of the spleen is greater than that of the liver or kidneys (**FIGURE 5**).

The **left kidney** can be found between the 16th and 17th intercostal spaces and the first to third lumbar vertebrae, medial or deep to the spleen (**FIGURE 6A**), between the level of the tuber coxae and the tuber ischii.[8,9] Rarely, the left kidney may directly appose the left body wall.[5] Gas in the small colon or left colon or lung may preclude transabdominal viewing of the left kidney.

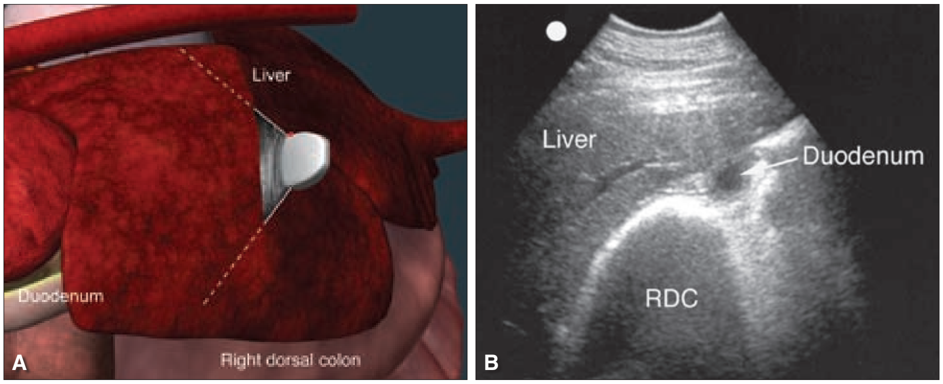


Figure 11. (**A**) Anatomy of the cranial mid right abdomen, and the transducer position for imaging the liver, duodenum, and right dorsal colon. The patient's head is to the right of the image. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 11b. (**B**) The displayed image from the transducer positioned in Figure 11a. The dorsal edge of the image is to the left. *RDC* = right dorsal colon. *Courtesy of The University of Georgia Glass Horse Project.*

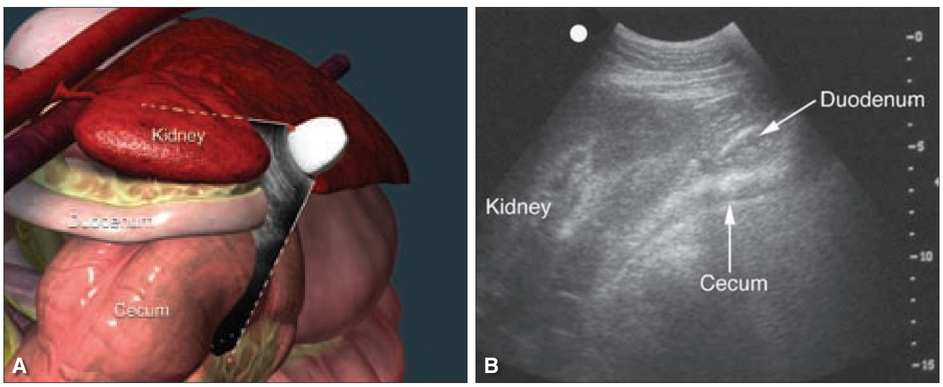


Figure 12. (**A**) Anatomy of the caudodorsal right abdomen, and the transducer position for imaging the right kidney, duodenum, and cecum (base). The patient's head is to the right of the image. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 12b. (**B**) The displayed image from the transducer positioned in Figure 12a. The dorsal edge is displayed to the left of the image. *Courtesy of The University of Georgia Glass Horse Project.*

The left kidney is 15 to 18 cm in length, but the long axis (i.e., the dorsal plane parallel to the spine) is difficult to measure because of interference by the ribs.[9] The height (11 to 15 cm in the slightly oblique transverse plane) and thickness (depth; 5 to 6 cm) are more reliable measurements. The corticomedullary junction should be distinct, and the cortex is approximately 1 cm thick (**FIGURE 6B**). The renal cortex is more echogenic than the adjacent medulla, except in areas of the medulla where interlobar vessels course centrally to form the renal pyramids, which are most readily visible in the middle regions of the kidney compared with the poles.[9] The walls of the renal pelvis are best imaged in the hilus and also appear parallel to diverging hyperechoic lines that are often accentuated by the presence of fat in the renal pelvis.[9] The renal artery and vein can sometimes be identified medial to the kidney at the hilus in transverse planes. The normal left ureter cannot be imaged.

Ventromedial to the spleen, the **left ventral colon** can be identified by its sacculated wall (**FIGURE 7**) and "sluggish" motility. The wall of the colon should measure <4 mm. The **left dorsal colon** is not sacculated and may be located dorsal (**FIGURE 8**), lateral, medial, or even ventral to the left ventral colon. Gas in the left ventral colon may preclude identification of the left dorsal colon when the latter lies medial or dorsal to the left ventral colon. Gas in the colon typically generates a hyperechoic wall with an indistinct luminal border and intraluminal acoustic shadowing that precludes identification of the contents and the medial walls.

The **small colon** is located in the left paralumbar fossa medial or ventral to the spleen. Because of its small diameter, sacculations, and packed serpentine loops that suspend from the dorsal mesocolon, often only small sections of the loop surfaces are visible ultrasonographically as short, sharply curving, hyperechoic lines (**FIGURE 9A**). As with the large colon, the motility of the small colon is slow and luminal gas typically prevents visualization of the contents and the distal walls (**FIGURE 9B**).

The **small intestine** is hard to visualize in healthy horses unless a peristaltic wave generates transient expansion of the lumen from movement of fluid contents. The medial location of the ileum precludes distinct identification. The jejunum is usually found in the left inguinal area, medial to the spleen and the left ventral colon (**FIGURE 10**). The small intestine has the most visible motility of any part of the GI tract, with peristaltic waves producing rhythmic contractions. The fluid in the lumen helps visualize the wall to determine its thickness (i.e., 2 to 4 mm) and visualize the far wall along its long or short axis. In healthy horses, luminal diameters rarely exceed 3 cm and, during complete contraction with peristalsis, a distinct lumen becomes difficult to discern. Fasting and/or sedation using an α_2 agonist decreases motility of the small intestine.[2,3]

Ultrasonographic Anatomy of the Right Side of the Abdomen

The liver, descending duodenum, and right dorsal colon have a characteristic proximity and can be identified in the right rostral abdomen at the level of the shoulder (**FIGURE 11A**). The **liver** can be located from the sixth to the 14th intercostal spaces between the diaphragm and the right dorsal colon (**FIGURE 11B**). Only a small portion of the right side of the liver can be imaged, so its size is estimated based on its expanse across the intercostal spaces.[5] It is unusual for the liver to be seen beyond the 15th intercostal space or in the same transverse plane as the right kidney, except at the most rostral aspect of the kidney.[4] The ventral edges of a

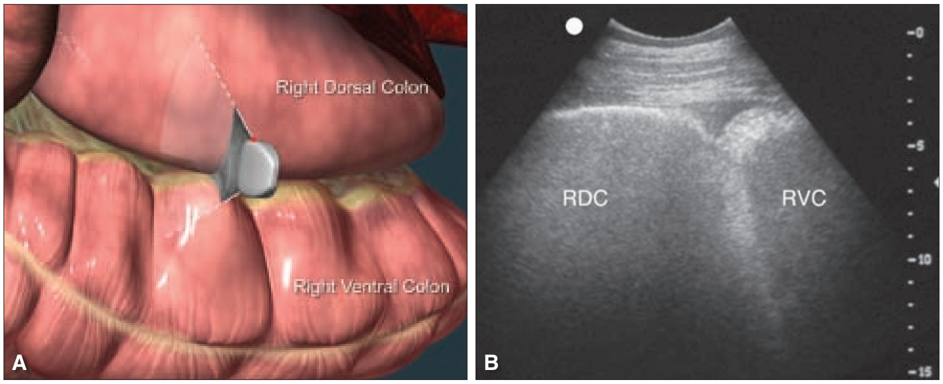


Figure 13. (**A**) Anatomy of the right abdomen, and the transducer position for imaging the right colon. The patient's head is to the right. The red mark on the transducer orients the ultrasonographer to the projected image in Figure 13b. (**B**) The image from the transducer positioned in Figure 13a. The right dorsal colon (*RDC*) is displayed on the left (dorsal) side of the image. *RVC* = right ventral colon. *Courtesy of The University of Georgia Glass Horse Project.*

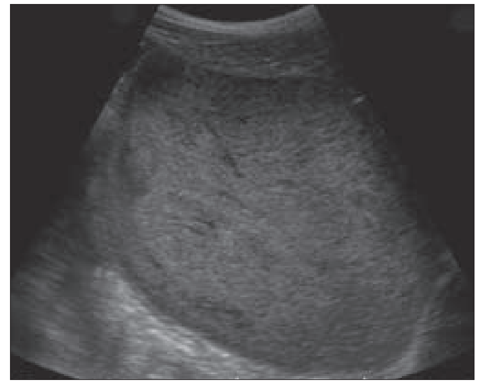
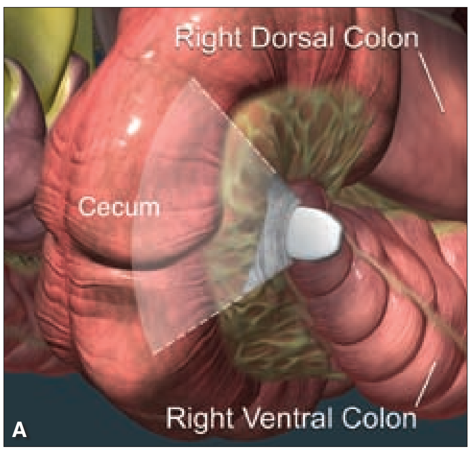


Figure 15. This image was obtained in the caudoventral abdomen at the brim of the pelvis and shows the hyperechoic contents of a normal equine urinary bladder. *Courtesy of The University of Georgia Glass Horse Project.*



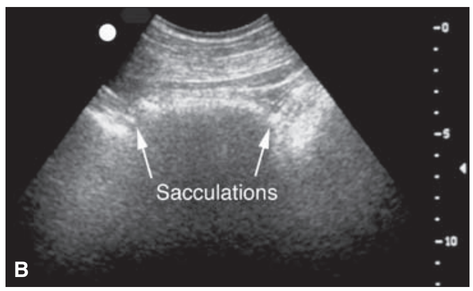


Figure 14. (**A**) Anatomy of the right caudal abdomen, and the transducer position for imaging the cecum. (**B**) The image from the transducer positioned in Figure 14a. Note the sacculations in the cecal wall. *Courtesy of The University of Georgia Glass Horse Project.*

normal liver are distinctly sharp. As with the spleen, the architecture of the liver is relatively homogenous, but more vessels are visible in the liver and the general echogenicity of the liver is less than that of the spleen (**FIGURE 5**). Portal veins have more connective tissue in their walls and thus have more echogenic walls than the hepatic veins.[5] Short segments of smaller portal veins often appear as hyperechoic parallel lines (**FIGURE 5**). In some small horses, the portal vein can be seen entering the hilus deep on the medial side of the image. The common bile duct and its branches within the liver are not normally visible.[4,5]

The position of the **duodenum** is fixed by its suspending mesoduodenum. The duodenum can reliably be found descending the right middle abdomen at approximately the level of the shoulder and is located between the liver and the right dorsal colon (**FIGURE 11A**), where it can be imaged transversely along its short axis. As with the jejunum, to locate the descending duodenum, the ultrasonographer must wait for a peristaltic contraction to deliver fluid through the lumen (**FIGURE 11B**). Otherwise, the duodenum appears flattened. It is unusual for the duodenal diameter to exceed approximately 3 cm in healthy horses during peristaltic propulsion of ingesta.[10] The duodenum contracts one to four times per minute in fed horses,[10] but contractions are less frequent in anorectic, starved, or heavily sedated horses. The duodenum can be followed to the level of the ventral right kidney (**FIGURE 12A**), where it crosses medially into the abdomen and is no longer distinguishable. The wall of the duodenum is <4 mm thick (**FIGURE 12B**).

The **right dorsal colon**, which has no sacculations, is immediately caudad to the liver and duodenum. The wall of the right dorsal colon consistently appears as a hyperechoic curved line adjacent to the liver (**FIGURE 11B**). If the ultrasonographer locates the right dorsal colon and slides the transducer ventrally, the junction between the right dorsal and right ventral colon is often identifiable (**FIGURE 13**). The right ventral colon has sacculations. Like the left colon, the right colon has a wall that is <4 mm thick, sluggish motility, and contents and far walls that are normally obscured by luminal gas.

The **cecum** extends from the right paralumbar fossa to the ventral midline (**FIGURE 14**). The cecum is sacculated, and its motility is usually more apparent than that of the colon. The cecum wall is <4 mm thick, and gas in the lumen precludes imaging the contents and far wall.

Gas in the cecum, right dorsal colon, or lungs sometimes obscures visualization of the **right kidney**, which can normally be found in the rostral right paralumbar fossa to the 16th intercostal space[8,9] (**FIGURE 12**). The right kidney is 13 to 18 cm in height (the slightly oblique transverse plane), 13 to 15 cm in length (the dorsal plane), and 5 cm thick.[9] The ureters are usually difficult to image, but the proximal right ureter sometimes appears as a hyperechoic circular structure in the hilus. The architecture of the right kidney is similar to that of the left kidney.

The **urinary bladder**, nongravid uterus, and ovaries are best imaged transrectally in adult horses. When full, the urinary bladder may be found ventrally at the most caudal aspect of the abdomen near the pelvic brim. Because of the presence of mucus and calcium, urine in adult horses often appears very echogenic (**FIGURE 15**).

The transverse colon, adrenal glands, and pancreas are not usually identifiable via transabdominal ultrasonography.[5] Only minute pockets of peritoneal fluid should be identifiable, and they are typically in the rostroventral area of the abdominal cavity.

Conclusion

Although ultrasonography can be an extremely valuable diagnostic tool, the information it provides is most beneficial when the ultrasonographer uses it in conjunction with other clinical and diagnostic findings. If ultrasonography is used as a single diagnostic modality, its limitations, including limited depth of view, gas interference, and artifactual findings, can hinder its usefulness and lead to erroneous conclusions. When possible, it is prudent to confirm architecture abnormalities in more than one plane to add credence to the findings.

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1. Which ultrasound transducer would be the best choice for transabdominal imaging of an adult horse?

- **a.** 8.5 MHz, curvilinear
- **b.** 7 MHz, linear
- **c.** 3.5 MHz, curvilinear
- **d.** 5 MHz, sector

2. For transabdominal ultrasonography of horses, the position of the ribs dictates that most images are obtained in the __________ plane.

- **a.** transverse
- **b.** sagittal
- **c.** dorsal
- **d.** frontal

3. Which part of the GI tract of an adult horse has the thickest wall?

- **a.** the stomach
- **b.** the ileum
- **c.** the right dorsal colon
- **d.** the pelvic flexure

4. Which part of the stomach is most readily imaged from the left side of a horse?

- **a.** cardia
- **b.** pylorus
- **c.** lesser curvature
- **d.** greater curvature

5. Which of the following organs is most echogenic?

- **a.** the liver
- **b.** the kidneys
- **c.** the spleen
- **d.** the small intestine

6. The wall of the small intestine is usually approximately ____ mm thick.

- **a.** 1 to 2
- **b.** 2 to 4
- **c.** 4 to 6
- **d.** 6 to 8

7. Which part of the GI tract of an unsedated horse has the most visible motility?

- **a.** the stomach
- **b.** the small intestine
- **c.** the cecum
- **d.** the ascending colon

8. Which luminal structures of the liver have the most echogenic walls?

- **a.** portal veins
- **b.** hepatic veins
- **c.** biliary ducts
- **d.** none of the above

9. The duodenum can reliably be identified by its proximity to the

- **a.** spleen.
- **b.** right ventral colon.
- **c.** stomach.
- **d.** right dorsal colon.

10. Which of the following segments of the equine intestinal tract does not contain sacculations?

- **a.** the right ventral colon
- **b.** the left ventral colon
- **c.** the left dorsal colon
- **d.** the small colon