REVIEW OF NORMAL EQUINE GASTROINTESTINAL ULTRASONOGRAPHY

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INTRODUCTION

The recent introduction of more affordable and portable ultrasound equipment makes it possible to perform transabdominal ultrasonography in the field situation on equine patients. The unique feature of this review does not lie in the information provided, but in the way that the information will be provided. During the presentation, standard ultrasound images of the healthy equine abdomen will be accompanied by three-dimensional computer-generated animations that were designed to orient the viewer to normal anatomy.*

GETTING STARTED

There are several different types of ultrasound transducers, though most imaging of the adult horse’s abdomen is done with a 2 to 5 MHz curvilinear array transducer. 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. Ideally, prior to ultrasonography, the patient's hair should be clipped with a number 40 blade and the skin should be cleansed with isopropyl alcohol. Couplant gel should be liberally applied. If clipping the hair is not an option, soaking the hair with isopropyl alcohol will often suffice. Many horses will tolerate transabdominal ultrasonography without sedation. If however, sedation is needed, be mindful that alpha two agonists, such as xylazine and detomidine, will induce a transient state of ileus, and thus intestinal motility may be reduced and the luminal diameter of the small intestine may appear more dilated than in a patient that is not sedated.2,3

When performing ultrasonography, there are four key elements that will greatly facilitate the examination: being aware of the orientation of the probe with respect to the patient, using information on the depth of the viewing field, understanding how the image is generated by the ultrasound machine, and having knowledge of normal anatomy with respect to probe placement.

ORIENTATION OF THE PROBE

Ultrasound transducers have a physical mark on them that provides orientation of the transducer's placement on the patient relative to the projected ultrasound image on the viewing screen. Because much of abdominal ultrasonography is 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 with the probe marker “up.” In other words, the transducer marker is at the 11 to 12 o’clock position or toward the “dorsal” aspect of the patient. When the image is displayed on the viewing screen, most ultrasound machines display the position marker on the screen. This screen position marker is intended to orient the ultrasonographer to the displayed image. For example, if the orientation marker on the transducer is 11 to 12 o’clock relative to the patient to obtain a transverse plane image (slicing across the long axis of the body), and if the ultrasound machine normally displays the probe orientation mark in the upper left hand corner of displayed image, then the ultrasonographer knows immediately that the portion of the image on the left-hand side of the screen represents the dorsal aspect of the captured image. Knowing the orientation of the transducer marker relative to the patient and the way the ultrasound
machine normally displays its images greatly facilitates orientation to the structures that appear in the image on the screen. Be mindful of the fact that you can manually "flip" the image display on most ultrasound machines by pressing a left/right or top/bottom inversion key.

DEPTH OF VIEW

In any ultrasound examination, it is important to be mindful of the depth of the field of view. The selection of the appropriate frequency for a transducer is the key to producing a high-quality image that is most suitable for the depth of display. Recall that higher frequency probes provide sharp images; however, this clear resolution is compromised as the depth of the viewing field increases. If using a fixed single frequency probe, the 3.0 or 3.5 MHz curvilinear probe is the most suitable compromise to accommodate imaging of the majority of the abdominal viscera. You can simply orient yourself to the depth of view by looking at the scale of the displayed image. You can be easily tricked into believing that something is missing from the field of view, only to realize that the depth setting is too shallow to identify the structure of interest. It is also easy to fool yourself into thinking that a lesion is enormous, only to realize that the depth of view is only a few centimeters and therefore magnified.

HOW THE 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. While denser tissues have greater acoustic impedance, it is the interface between adjacent tissues, or between tissues within the same organ, that determines how much of the sound wave is reflected back to the transducer. The more sound reflected to the transducer, the "whiter" the image appears on the viewing screen. These tissue interfaces are called “echogenic” or “hyperechoic.” In contrast, less dense tissues reflect less sound and are called “anechoic” or “hypoechoic” and appear blacker. Knowing that tissue interface difference is what is primarily responsible for reflecting sound back to the transducer, more sound waves should echo back 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 walls has an acoustic impedance that is several thousand fold greater than that of the free gas inside the adjacent lumen. Consequently, the image at this soft tissue to gas interface appears as a fuzzy hyperechoic border. Since 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. Remember, gas within a large viscus is actually one of the greatest limitations to gastrointestinal ultrasonography: the gas prevents visualization of deeper structures. While imaging a patient, keep in mind that fluid and heavier structures will fall to the dependent side and gas will float to the nondependent side and obstruct deeper views.

With a very high resolution linear array transducer, one may be able to see up to 5 layers to the gastrointestinal wall. Though most typically, when using the standard approach with a 3 to 3.5 MHz transducer, and depending on the surrounding tissue and the contents of the lumen, only three or less layers are normally visible (hyperechoic serosa, hypoechoic muscularis to mucosa, hyperechoic interface with lumen).
INTEGRATION OF KNOWLEDGE OF NORMAL ABDOMINAL ANATOMY

When scanning the equine abdomen, it is helpful to use a systematic approach, scanning from top to bottom, rostral to caudal, left and right sides. Careful attention should be paid to the spatial relationship of the viscera, as this may be important in the distinction between normal and abnormal. The walls of some sections of the gastrointestinal tract appear strikingly similar and without knowledge of where the transducer is placed on the abdomen, they may not be distinguishable. Transabdominal ultrasonography not only provides structural information, but it can provide some idea of function i.e. motility. Recall that heavy sedation can cause transient ileus and mildly dilated small intestine.

Ultrasonographic Anatomy of the Left Side of the Abdomen

If imaging is started on the left rostral side of the abdomen, the stomach should be located deep to the spleen between the ninth to the thirteenth intercostal spaces at approximately the level of the shoulder. In this location, the only part of the stomach that normally can be seen is the wall of the greater curvature, which can be reliably identified as a curved line with proximity to the adjacent spleen and the gastrosplenic vein. If the stomach extends beyond the 14th intercostal space in a horse that has not recently eaten, it would be an indication of gastric distension or displacement by other viscera. The stomach has the thickest wall of the gastrointestinal tract, measuring 7 mm from the serosal to the mucosal/lumen interface. When the stomach is empty, the wall may be up to 1 cm thick. Since only the dorsal portion of the greater curvature can be seen and the lumen generally contains gas in this location, often the contents of the stomach are not visible and the curved wall appears hyperechoic. If gastric fluid is present ventrally, a distinct gas/fluid interface may be apparent in the lumen.

The size and location of the spleen is highly variable, though it should be identifiable immediately adjacent to the body wall, from the left ventral eight intercostal space to the paralumbar fossa. It may remain to the left of the midline, or extend slightly beyond the right of the ventral midline. The only measurement of the spleen that can be reliably obtained is its central thickness or depth, which usually is less than 15 cm. In some horses, in the rostral ventral left abdomen, the most rostral aspect of the spleen can be seen either lateral or medial to the liver. Normally the spleen's ultrasonographic architecture is homogenous with vessels rarely visible. The general echogenicity of the spleen should be greater than that of the liver and kidney.

The left kidney can be found between the sixteenth to seventeenth intercostal space and the first to third lumbar vertebra, medial or deep to the spleen, between the level of the tuber coxae and the tuber ischi. Rarely, the left kidney may directly oppose the left body wall. Gas in the small colon or left colon or lung may preclude transabdominal viewing of the left kidney. The left kidney thickness or depth (lateral to medial) is often the most reliable measure of the left kidney and is usually between 7 to 9 cm in Thoroughbreds. The corticomedullary junction should be distinct, with the cortex approximately 1 cm thick. 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, as compared to the poles. Adjacent to the renal pyramids, centrally located at the rostral and caudal regions of the kidney are the terminal recesses wherein urine is collected and carried to the pelvis. In these areas, the renal pyramids appear as distinct hypochoic "circles," converging on the hyperchoic and indistinctly parallel lines of the terminal recesses. The walls of the renal pelvis are best imaged in
the hilus and also appear as parallel to diverging hyperechoic lines that are often accentuated by the presence of fat in the renal pelvis. 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.

The left colon is located ventromedial to the spleen. The left ventral colon is sacculated and has “sluggish” motility. The wall of the colon should measure less than 4 mm. The left dorsal colon is not sacculated and may be located dorsal, 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 it lies medial or dorsal to the left ventral colon. Gas in the colons typically generates a hyperechoic appearing 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. With its small diameter, sacculations, and packed serpentine loops that suspend from the dorsal mesocolon, often only small sections of the surface of loops are visible ultrasonographically as short sharply curving hyperechoic lines. Like the left colon, the motility is slow and luminal gas typically prevents visualization of the contents and the distal walls.

The small intestine is hard to visualize in normal 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 most reliably is found in the left inguinal area, medial to spleen and the left ventral colon. The small intestine has the most visible motility of any part of the gastrointestinal tract, with peristaltic waves producing rhythms contractions. The fluid contents of the lumen enables distinction of the wall thickness (2 to 4 mm) and visualization of the distal wall in either its long or short axis. In the normal horse, luminal diameters rarely exceed 3 cm and should be seen contracting down to obscurity. Fasting and sedation with alpha-two agonists will individually and additively decrease motility of the small intestine.

Ultrasonographic Anatomy of the Right Side of the Abdomen

Three anatomic structures that provide characteristic proximity that can be identified in the right rostral abdomen at the level of the shoulder are the liver, the descending duodenum, and the right dorsal colon. The liver can be located from the sixth to the fourteenth intercostal spaces between the diaphragm and the right dorsal colon. Air in the lungs dorsally often interferes with hepatic imaging. Only a small portion of the right side of the liver can be imaged and estimates of size rely on its expanse across intercostal spaces. It is unusual for the liver to be seen beyond the fifteenth intercostal space or in the same transverse plane as the right kidney, except at the most rostral aspect of the kidney. The ventral edges of the normal liver should be distinctly sharp. Like the spleen, the architecture of the liver is relatively homogenous, though more vessels are visible in the liver and the general echogenicity of the liver is less than the spleen. Portal veins have more connective tissue in their walls and thus have more echogenic walls than the hepatic veins. Often short segments of smaller portal veins appear as hyperechoic parallel lines. In some smaller 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.

The position of the duodenum is fixed by its suspending mesoduodenum. It can reliably be found descending the right middle abdomen at about the level of the shoulder and is located
between the liver and the right dorsal colon where it can be imaged transversely in short axis. Like the jejunum, patience must be exercised when looking for the descending duodenum as one must wait for a peristaltic contraction to deliver fluid through the lumen. Otherwise, the duodenum appears flattened. It would be unusual for the entire duodenal diameter to exceed approximately 4 cm in normal horses during peristaltic propulsion of ingesta.\textsuperscript{10} The duodenum contracts between 1 to 4 times per minute in fed horses,\textsuperscript{10} though contractions will be reduced in anorexic, starved or heavily sedated horses. The duodenum can be followed to the level of the ventral right kidney, wherein it crosses medially into the abdomen and is no longer distinguishable. The wall of the duodenum is less than 4 mm in thickness.

The right dorsal colon has no sacculations and consistently appears as a hyperechoic curved line adjacent to the liver. Once the right dorsal colon is located, if one slides the transducer ventrally, often the junction between the right dorsal and right ventral colons is identifiable. The right ventral colon has sacculations. Like the left colons, the right colons’ wall thickness should be less than 4 mm, motility is sluggish, and the contents and far walls are normally obscured by the presence of luminal gas.

The cecum extends from the right paralumbar fossa to the ventral midline. It is sacculated and motility is usually more apparent than in the colons. Wall thickness is less than 4 mm and gas in the lumen precludes imaging the contents and far wall.

Gas in the cecum, right dorsal colon, or lung sometimes obscures visualization of the right kidney which can normally be found in the rostral right paralumbar fossa to the sixteenth intercostal space.\textsuperscript{8,9} The thickness of the right kidney is 6.5 to 8.5 cm, lateromedially, in Thoroughbreds.\textsuperscript{9} Normally it is difficult to image the ureter, though the proximal right ureter can sometimes be seen as a hyperechoic circular structure in the hilus. The right kidney architecture is similar to that described for the left kidney.

The urinary bladder, nongravid uterus, and ovaries are best imaged in the adult horse transrectally. When full, the urinary bladder may be found ventrally at the caudal most aspect of the abdomen near the pelvic brim. Owing to the presence of mucous and calcium, urine in the adult horse often appears very echogenic.

REFERENCES


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