Ultrasound of the Adult Abdomen and Thorax

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1. Introduction
Diagnosis ultrasound is widely used in equine practice for a diversity of applications. Sonographic evaluation of the equine thoracic and abdominal cavities provides diagnostic information, the value of which is heavily influenced by the preparation of the patient and the technique and experience of the examiner. These proceedings will outline key strategies for making the most of thoracic and abdominal ultrasonography in the horse with considerations of case selection, patient preparation, equipment requirements, and examination technique.

2. Materials and Methods
Case selection involves understanding both manifestations of disease and the limitations of sonography as a modality. By far, the most common application of abdominal sonography in equine practice is the horse with acute signs of abdominal pain. For these patients, specific information is desired to make a rapid determination as to how to achieve the best outcome for the patient (referral vs on-farm treatment, surgical vs medical management vs euthanasia). The most appropriate approach to these patients is a limited, rapid examination that efficiently and specifically addresses these concerns. The fast localized abdominal sonography for horses (FLASH) technique achieves these goals in a systematic examination in seven discrete windows. Evaluation of the anatomy in these windows gives the examiner important data about the likelihood of a colonic displacement, distention of the stomach and/or small intestine, and the presence or absence of peritoneal and pleural effusions and requires only around 10 minutes to perform.1 As effective a tool as FLASH is at providing information about acute colic, however, it is inappropriate to apply this technique to other applications for abdominal sonography, including fever, chronic colic, diarrhea, liver or kidney dysfunction, anemia, abdominal distention, weight loss, and hypoproteinemia. To obtain meaningful information for aiding in the investigation of these clinical presentations, a full abdominal ultrasound is indicated. A comprehensive abdominal ultrasound is time consuming; to fully scrutinize each intercostal space and the ventral abdomen, up to one hour may be required. To maximize the use of this technique, the sonographer must also possess a commanding knowledge of the anatomy and sufficient experience to accurately interpret subtle alterations of the anatomy. Indications for thoracic ultrasound include fever, tachypnea, cough, sternal edema, pleurodynia, and a history of trauma with suspicion of rib fractures, hemothorax, or pneumothorax. Pulmonary lesions are detected sonographically only if they extend to the pleural surface, and lesions that are confined to the airways, deep to air-filled parenchyma, such as equine asthma, are not sonographically accessible. Ultrasound evaluation of the thorax is most useful for detecting pleural effusion, rib
fractures, and infections and neoplastic processes that occur at the pleural surface. Familiarity with the anatomy of the pleural space and diaphragm is required to accurately interpret the images obtained. Regardless of the type of examination, proper, thorough patient preparation is essential for the acquisition of high-quality images. For ideal image quality, as much of the haircoat as possible should be removed by clipping with a #40 blade and the skin washed with soap and warm water. Application of gel to the skin provides a coupling substrate. Warming the gel prior to application promotes vasodilation in the skin and therefore improves transmission of sound waves. If clipping is not possible, the haircoat should at least be brushed thoroughly to remove dirt and debris, as dirt will block the transmission of sound waves. If not clipping, one should use isopropyl alcohol or warm water instead of gel to wet the hair and provide a coupling substrate (Fig. 1). When using alcohol, especially in cool environments, evaporation will cause piloerection and impede further imaging, even when alcohol is reapplied. Thus, applying alcohol to one small area at a time as that area is being evaluated is strongly recommended over dousing the entire side of the horse at the beginning of the examination. Visceral gas is a major impediment to visualization of the abdominal contents of the horse. Additionally, the small intestine is a common site for digestive dysfunction, resulting in weight loss, protein loss, and chronic intermittent colic, but is frequently poorly visualized due to colonic gas, its anatomic location, and the presence of ingesta within the small intestinal lumen. Fasting has been shown to improve the effect of both reducing gas in the large colon and slowing the peristalsis of the small intestine, which favors it sinking to the ventral abdomen where it can be more readily examined. This effect has been demonstrated to improve measures of small intestinal visibility and definition, and although improvement of the visibility of other organs has not been critically assessed, fasting may also improve imaging access to other organs, such as the liver. Circumstances obviously prevent a pre-examination fast in acute colic, but all horses undergoing scheduled full abdominal sonography should be fasted (with free access to water) for at least 12 hours before the exam. If ultrasound and gastroscopy are being performed at the same visit, ultrasound would ideally be performed first to avoid the impediment of insufflated gas in the stomach and small intestine. The astounding advances in imaging technology have opened up a variety of options to the equine practitioner. To perform a thorough abdominal examination, a low-frequency transducer of either curvilinear or sector configuration is ideal. The advantage of these configurations is the pie-shaped image, which provides a wide image window through a relatively small transcutaneous footprint. Linear probes (e.g., “tendon” or “rectal” transducers) can be used for thoracic evaluation and can be used to obtain limited information about the abdominal cavity, but they have insufficient depth/power to penetrate the deeper tissues of the abdomen. Because the pleural surface is relatively close to the body surface, higher frequency transducers can be very useful for thoracic evaluation, but a curvilinear configuration remains the preferred choice due to the increased width of anatomy that can be evaluated at one time (Fig. 2). A linear transducer is often the ideal choice for evaluating the ribs when fractures are suspected, however. Many ultrasound systems have preset exam settings, which are a great starting place, but they cannot account for all of the physical (overall size, breed, and adiposity) and physiological (hydration and ambient temperature) differences between patients. This means that the examiner is required to “finesse” the settings to account for these differences and to account for the depths and densities of various organs. Settings that are frequently adjusted include depth, frequency, focus, gain, and time/gain compensation. Depth should generally be adjusted so that the organ of interest just fills the screen; this maximizes the information contained in the viewing

Fig. 1. Effect of patient preparation for equine abdominal sonography. These images were obtained minutes apart from the same horse with no change in machine settings. A, Obtained with isopropyl alcohol applied to clean, unclipped hair. B, Obtained with ultrasound coupling gel applied to skin after clipping with a #40 blade.
area (Fig. 3). Because of the various sizes and locations of abdominal organs within the body, depth is constantly adjusted in the course of abdominal sonography. The “frequency” refers to the number of sound waves that pass a fixed point per second. As frequency increases, the level of detail in the image increases, but the ability of the sound waves to penetrate tissue decreases. Therefore, frequency should be adjusted to the highest frequency that yields a diagnostic image at the required depth. Like depth, frequency is adjusted up and down to accommodate variable depths and tissue densities throughout the abdominal scan. Focus refers to the region of the screen that has the best resolution, which is analogous to the focus of a camera. For most systems, the zone in focus is indicated with a cursor on the right of the screen and may be single or multiple. Use of more than two focal zones slows processing speed, defeats the purpose of bringing the object of interest into focus, and is therefore not recommended. On certain systems, the zone in focus is always the area in the center between the most superficial structures and the limit of depth. When using these systems, adjusting the depth also has the function of changing the focus. Gain is the brightness of the image. It should not be altered until after the frequency has been optimized. Time/gain compensation changes the gain throughout the depth of the image, which is especially important to use when evaluating deeper structures to produce an image with even brightness throughout and not overly bright in the superficial structures and not bright enough in the deeper ones. This principle can also be used in reverse in cases of effusion when acoustic enhancement results in the deeper structures to be overgained. Thoracic sonography generally requires less manipulation of the images during the examination due to the fact that the pleural surface is generally the sole object of interest and occurs at a roughly consistent depth. In the case of pathology, however, adjustments will need to be made as in abdominal sonography. Regardless of what is being evaluated, labels are required to identify (at least) the anatomic location in the image and the orientation of the transducer with respect to the patient’s body. The anatomic location seems logical and obvious when the anatomy is normal but is often neither in pathologic states. The label should indicate the side of the horse and the general region and provide more information if relevant. For thoracic imaging, it is useful to divide the trunk into thirds.

Fig. 2. Comparison of a thoracic ultrasound image obtained with a curvilinear transducer and straight linear transducer. Note that both are diagnostic quality images. A, Image obtained with a curvilinear transducer (1- to 8-mHz variable frequency). B, Image obtained with a straight linear transducer (4- to 10-mHz variable frequency).

Fig. 3. The effect of depth on image quality. Note the increased detail of the renal parenchyma in B. A, The left kidney and spleen imaged at 30 cm of depth. B, The left kidney and spleen imaged at 25 cm of depth.
from ventral to dorsal and indicate that and the intercostal space number on the label. For the examination, as for any examination, the practitioner should follow the same pattern each time to maximize muscle memory and to avoid errors. This pattern should be logical and easy to the operator; no one system is perfect for everyone. The author begins every evaluation on the left side in the most dorsal imaging window; for the abdomen, this is the left paralumbar fossa, and for the thorax, this is the left 15th intercostal space just ventral to the epaxial musculature. The examination proceeds by sliding down each intercostal space from dorsal to ventral and then, for the abdominal evaluation, sliding from cranial to caudal (e.g., with the hair) along the ventral abdomen. When evaluating the thorax, the author interrogates each intercostal space starting dorsally at the epaxial muscles and terminating at the diaphragm. Care is needed in both thoracic and abdominal sonography to orient the transducer parallel in the intercostal space and perpendicular to the organ of interest. A fanning technique within intercostal spaces is useful to obtain images cranial and caudal to the intercostal spaces. When performing these examinations, images should be saved even when the anatomy appears to be normal. Representative images of the normal abdomen include at a minimum the nephrosplenic space, (including the entire left kidney), the tail of the spleen, the stomach, the liver/spleen interface, the right kidney and duodenum, the right dorsal colon adjacent to the liver, and the ventral abdomen. Representative images of the normal thorax include at a minimum a sampling of intercostal spaces at the level of the diaphragm; the author generally collects images at the 12th, 8th, and 6th intercostal spaces on each side of the thorax. When pathology is noted, more images are generally required to demonstrate the nature and extent of the abnormalities. Extremely abnormal findings may require additional annotation for clarity.

3. Results/Discussion
Abdominal and thoracic ultrasound provide useful diagnostic and prognostic information in both acute and chronic disease. Careful case selection, thorough patient preparation, knowledge of machine settings, accurate annotation, and well-practiced technique are all key elements of making the most of this imaging modality.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author has no conflicts of interest.

References