Ultrasound and the Nonacute Abdomen: The Abdominal Organs

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The ability of ultrasound to detect abnormalities of the kidneys, liver, and spleen has made tremendous strides over the past 10 years due to technological advancements in ultrasound equipment and increased availability of skilled equine ultrasonologists. As our knowledge base continues to grow, increased awareness is important for owners and veterinarians to understand the diagnostic potential of abdominal ultrasound. Evaluation of abdominal organs is best performed as part of a complete abdominal ultrasound exam. Ultrasound-guided procedures are often required to differentiate between various infectious, inflammatory, and neoplastic disorders. Author’s address: Clinical Large Animal Ultrasound, Department of Surgical and Radiological Sciences, University of California, One Shields Avenue, Davis, CA 95616; e-mail: mbwhitcomb@ucdavis.edu. © 2012 AAEP.

1. Introduction

Evaluation of the abdominal organs, including the kidneys, liver, and spleen, is generally performed as part of a complete ultrasound examination in nonacute patients. Many horses with hepatic, renal, or splenic abnormalities present with nonspecific clinical signs similar to those in horses with gastrointestinal tract disorders. Complete blood count (CBC) and serum chemistry analysis may be unremarkable or show only evidence of inflammation such as hyperfibrinogenemia and hyperglobulinemia. Subsequently, a full exam is required to maximize diagnostic yield in many cases. In other horses, clinical exam findings and serum biochemistry analysis may indicate primary renal or hepatic disease, in which case the examiner may choose to focus on the urinary tract or liver, respectively. Although horses with abdominal organ disorders infrequently present as acute colic patients, cursory examination of abdominal organs can yield important information during routine colic ultrasound exams.

Admittedly, mastery of abdominal ultrasound requires experience and patience, much more so than basic ultrasound of the acute abdomen. Similar to any anatomic region, however, cursory examination is possible by a motivated practitioner equipped with appropriate ultrasound equipment. It is equally important for field practitioners to understand our increased ability to diagnose and treat disorders of abdominal organs in the referral setting. Ultrasound findings often help guide treatment planning, including the need for medical therapy or surgical intervention. Not only do we gain valuable information about the appearance of abdominal organs, ultrasound-guided biopsy and/or aspirate can be used to determine the underlying etiology, to establish an appropriate treatment plan, and for prognostication.

Ultrasonographic Technique

A low-frequency (2–5 MHz) curvilinear transducer is necessary to evaluate abdominal organs in the adult...
horse due to their deep location (15 to 30 cm) relative to the skin surface. This transducer is available for most of today’s ultrasound machines, the majority of which are able to obtain exceptionally high-quality abdominal images. In contrast, a rectal transducer can only penetrate to 5 to 10 cm, which is insufficient to image the left kidney and the majority of the spleen, liver, and right kidney from the transcutaneous window. A rectal transducer can be used to image the caudal portion of the left kidney and spleen during transrectal examination.

For the highest quality images, the entire abdomen should be clipped with #40 blades, especially in older, obese, or thick-coated horses that tend to image poorly (Fig. 1). Alcohol saturation can produce diagnostic quality images, but the subtle nature of many ultrasonographic findings in the nonacute abdomen may not be detectable without clipping. After clipping, the skin should be cleaned with a wet sponge to remove dirt and debris, and ultrasound gel is then applied.

A systematic approach to each exam is important for consistency and to improve diagnostic yield. At the University of California, Davis (UC Davis), the entire abdomen is evaluated in the majority of nonacute patients presenting to the Large Animal Ultrasound Service. Each side of the abdomen is divided into three regions: (1) paralumbar fossa/flank region (PLF); (2) 5th through 17th intercostal spaces (ICS) from the ventral lung margins to the costochondral junctions; and (3) ventral abdomen from the sternum to the inguinal region. The exam should be performed in the same manner, regardless of clinical suspicion of cause. Structures evaluated from the right side of the abdomen include the cecum and cecal mesentery, right kidney, right liver lobe, duodenum, and right dorsal colon. The right ventral colon is primarily visualized from the right ventral abdomen. Structures evaluated from the left side of the abdomen include the left kidney, spleen, stomach, and left liver lobe. The left dorsal and ventral colons are seen predominantly from the left ventral abdomen.

Scanning depth should be adjusted frequently during the exam to best image the superficial and deep parenchyma of each organ. No single depth setting is appropriate for all abdominal organ imaging. An abdominal program or preset should be selected to maximize abdominal detail. Time-gain compensation controls should also be adjusted for deep cavity imaging (Fig. 2).

Renal and Urinary Tract Ultrasound

Specific indications for renal ultrasound include azotemia, hematuria, pollakiuria, dysuria, or abnormal findings of cystoliths, ureteroliths, or left renal enlargement on rectal palpation.\(^7\)\(^-\)\(^11\) It is important to remember that horses with significant renal abnormalities may present with a normal CBC and serum biochemical profile.\(^12\)

The left kidney is visible transcutaneously and transrectally. Transcutaneously, the left kidney is located deep to the spleen in the left PLF region and the left 15\(^{th}\) to 17\(^{th}\) ICS at a scanning depth of 20 to 30 cm (Fig. 3). The best images are often obtained in the left 16\(^{th}\) to 17\(^{th}\) ICS; however, the kidney should be imaged from all possible windows. At UC Davis, we routinely use a “special” technique to image the left kidney that entails placing the transducer caudal to the last rib, midway between the tuber coxae and stifle, and aiming in a dorsocranial direction. By applying gradual force with each expiration, the transducer is effectively brought closer to the left kidney and a superior image obtained than with traditional techniques. Transrectally,
the left kidney is typically visible at arm’s length; however, only the caudal portion of the kidney can be seen. The right kidney is seen dorsally in the right 15th to 17th ICS at a more superficial scanning depth of 15 to 20 cm, compared with the left kidney. The right kidney cannot be imaged transrectally in most horses.

Renal ultrasonographic parameters include size, shape, cortical echogenicity (hypoechoic to the adjacent spleen), cortical thickness, medullary echogenicity (hypoechoic to the cortex), and corticomedullary distinction. The renal pelvis should be evaluated for the presence of nephroliths and dilation (pyelectasia). Reported renal size measurements are somewhat variable, and horse size should be considered when interpreting measurements. In our experience, normal adult kidneys range from 5 to 9 cm in width and 15 to 19 cm in length; however, a recent study reported smaller measurements than that described by Reef and that of our own clinical experience.1,13

Small kidneys are generally associated with chronic renal failure.7 Affected kidneys often show a distorted shape, increased cortical echogenicity and thickness, and poor corticomedullary distinction and may have nephrolith(s) or peripelvic mineralization. Some are nearly unrecognizable as kidneys (Fig. 4). In some horses with chronic renal failure, one kidney may appear to be end-stage and nonfunctional, with the contralateral kidney showing enlargement but relatively normal renal parenchyma.7

Enlarged kidneys with or without increased cortical echogenicity and thickness may be secondary to acute renal failure, urolithiasis, nephritis, pyelonephritis, hydronephrosis, abscessation, or, less commonly, neoplasia.1,7,9–12 Interventional procedures such as ultrasound-guided biopsy or aspirate are often necessary to differentiate between potential diagnoses. Horses with acute renal failure may have perirenal edema, seen as an anechoic fluid layer between the renal capsule and cortex (Fig. 5).

Renal parenchyma is seldom distorted in horses with acute renal failure; however, a clearly visible and discrete corticomedullary junction is often present. Renal abscesses have been reported and appear as variably shaped hypoechoic or hyperechoic areas within the renal cortex and/or medulla.12 The kidneys are the second most common abdominal organ to be affected in horses with internal Corynebacterium pseudotuberculosis infection. Care should be taken not to misinterpret the hypoechoic area visible in the deep medullary portion of the right kidney for a mass or abscess. Hematuria is not uncommon in horses with renal abscessation. Renal neoplasia is relatively uncommon in horses but may be encountered with some regularity at referral hospitals. Renal adenocarcinoma is the most common primary tumor, producing large masses that completely efface renal parenchyma (Fig. 6)14,15 Renal metastasis of other tumor types has also been reported.1
Horses with urolithiasis can present with hematuria after exercise, azotemia, and occasionally with signs of colic. Urolithiasis is regularly encountered by clinicians at our hospital. Nephroliths are easily recognized as hyperechoic structures within the renal pelvis that cast hard shadows (Fig. 7). Renal sludge appears similarly but may produce a “dirty” or less distinct shadow. Differentiation between nephroliths and renal sludge is not straightforward. Care should be taken not to misinterpret the hyperechoic appearance of the renal pelvis as nephrolithiasis. All horses with urolithiasis should undergo transcutaneous evaluation of both kidneys and transrectal evaluation of the entire urinary tract to rule out additional uroliths and for evidence of underlying renal disease. Transrectal evaluation of the bladder and ureters is also indicated in horses with distention of the renal pelvis because a downstream cystolith (Fig. 8) or ureterolith may be the cause for renal pyelectasia. Using a transrectal approach, the left and right ureters are evaluated individually (Fig. 9), beginning at the bladder trigone and following each as far cranially as possible. The left ureter can regularly be followed along its length to the left kidney. The majority of the right ureter is also visible; however, the ureteropelvic junction with the right kidney is rarely visible in normal or abnormal horses. The presence of ureteral motility is helpful to differentiate ureters from blood vessels and the vas deferens in male horses. The normal appearance of the caudal ureters has been described. Ureteroliths can be identified along the length of the ureter (Fig. 10).

In the author’s experience, urolithiasis is often associated with ureteral wall thickening regardless of the location of the stone. Most importantly, in cases of urolithiasis, the examiner should be reminded to perform bladder endoscopy after ultrasound examination. Gas that is introduced during endoscopy will obscure ultrasonographic visualization of urinary structures, and its hyperechoic appearance can be easily confused with uroliths.

Idiopathic renal hematuria should be a differential in horses with a large amount of frank blood in their urine. Affected kidneys show distention of the renal pelvis with echogenic material consistent with hemorrhage and clot formation. Renal archi-

Fig. 6. Renal enlargement and diffuse effacement of renal parenchyma in a horse with renal adenocarcinoma of the left kidney, visualized from the left paralumbar fossa region. Dorsal is to the right.

Fig. 7. Large nephrolith within the renal pelvis of the left kidney, visible from the left paralumbar fossa region, in a horse that presented for pollakiuria and microscopic hematuria due to a bladder stone. The horse had a previous bladder stone removed 3 years earlier, at which time nephroliths were also noted. Dorsal is to the right.

Fig. 8. Transrectal image of a large cystolith (arrow) within the urinary bladder of a 20-year-old Arabian gelding with hematuria.

Fig. 9. Normal transrectal image of the midportion of the right ureter.
Architecture is often otherwise unremarkable. Horses are typically unilaterally affected. Removal of the affected kidney has not been reported to be effective because the contralateral kidney may subsequently become affected. Biopsy has not been rewarding in horses to reveal the underlying cause of idiopathic renal hematuria.

Renal cysts may be identified as an incidental finding in normal horses. In such cases, a singular cyst is typically present. Multiple small cortical cysts may be found in horses with acute or chronic renal failure.

Liver
The liver is generally evaluated as part of a complete abdominal ultrasound but may be the primary focus in horses with elevated hepatic enzymes. Similar to horses with renal disease, horses with significant hepatic abnormalities may have normal hepatic enzymes. In such cases, clinicians should resist the temptation to dismiss abnormal hepatic ultrasound findings as a potential cause of clinical signs. Biopsy may prove useful to document the presence of active liver disease in such cases.

The right liver lobe (RLL) is visible ventral to the lung margins in the right 8th to 15th ICS (Fig. 11), although visibility can be quite variable within these ICS. The RLL should not extend to or beyond the costochondral (CC) junctions, in which case it is considered to be enlarged. The left liver lobe (LLL) is visible caudal to the heart in the left cranioventral abdomen in the 7th to 10th ICS. The LLL extends from the ventral lung margins to the CC junctions. The LLL may be considered enlarged when it extends into the left cranioventral abdomen; however, this may be present in some horses without hepatic pathology. The margins of the LLL are often difficult to evaluate due to shadowing created by the overlying CC junctions. In most horses, the LLL is located superficial to the adjacent spleen; however, it may occasionally be positioned deep to the spleen, in which case the LLL margins will appear falsely rounded. Echogenicity of the LLL should be hypoechoic to the adjacent spleen (Fig. 12). Scanning depth ranges from 10 to 30 cm and should be changed in each ICS to best evaluate the superficial and deep parenchyma of the liver.

Ultrasoundographic abnormalities include hepatomegaly, rounded margins (Fig. 13), changes in echogenicity (usually increased), decreased fine vascular markings, biliary/vascular fibrosis/inflammation, hepatoliths, biliary distention, and, less commonly, evidence of abscessation or neoplasia. Hepatomegaly and rounded margins may be seen with multiple disease processes, including hepatitis, cholangihepatitis, obstructive choledolithiasis, and neoplasia. Decreased fine vascular marking (FVM) is a nonspecific but significant finding and is often overlooked by less experienced imagers due to its subtle nature. Decreased FVM causes the liver to appear dense and similar in echotexture to the spleen. It may be the only sonographic abnormality in some horses with primary liver disease, in-
including horses with pyrrolizidine alkaloid toxicosis (Fig. 14). Horses with obstructive cholelithiasis are infrequently encountered at our hospital but can demonstrate a “parallel channel sign” secondary to distention of the bile duct adjacent to the portal vein (Fig. 15). The obstructive hepatolith may not be visible. When present, hepatoliths can be of variable echogenicity and create variable acoustic shadowing, in contrast to that seen with urolithiasis (Fig. 16).

Biliary or vascular inflammation or fibrosis is a nonspecific finding with many hepatic disorders that creates multiple small hyperechoic parallel lines scattered diffusely throughout hepatic parenchyma. These occasionally cast shadows, and care should be taken not to confuse this appearance with hepatoliths. Similarly, “starry sky” pattern was recently described in which multiple hyperechoic foci were found throughout the renal parenchyma in horses with granulomas. These regions showed variable shadowing and were differentiated from hepatoliths by their extrabiliary location.

Hepatic abscession can create hypoechoic and/or hyperechoic areas within the liver. The liver is the most common site for abdominal C. pseudotuberculosis infection, in which single to multiple coalescing hypoechoic areas can be found. Hepatic neoplasia is relatively uncommon. Affected livers often demonstrate a diffusely heterogeneous appearance, although discrete metastatic masses can be seen (Fig. 17).

Ultrasound-guided biopsy is often necessary to differentiate between hepatic abscession and neoplasia.

Spleen

Splenic abnormalities generally cause nonspecific clinical signs such as reduced appetite, weight loss, fever, depression, and malaise. Splenic disorders may occasionally cause colic symptoms in some horses, as neoplastic invasion of splenic tissue and other disorders can produce abdominal pain. It is rare for clinical features to direct a clinician to...
implicate the spleen as the source of clinical signs, with the exception of palpable splenic enlargement during rectal examination. Therefore, most splenic abnormalities are identified during a complete abdominal ultrasound exam.

The spleen is the predominant feature of the left abdomen and is visible throughout most left ICS, the PLF region, and left ventral abdomen. The spleen often extends to or slightly to the right of ventral midline in normal horses. Splenomegaly is difficult to objectively document because the normal spleen may show rightward displacement in horses with gastric distention or colon displacements. The spleen is the most echogenic of the three abdominal organs and should show an evenly homogeneous echogenicity (Fig. 18). The spleen appears less vascular than the liver, although the splenic vein is typically visible adjacent to the stomach.

The spleen is the least commonly affected abdominal organ in horses; however, splenic neoplasia is encountered with some frequency at referral institutions. Lymphoma is the most common splenic tumor in horses. Horses with splenic lymphoma often have an enlarged spleen and show diffuse infiltration of splenic tissue with heterogeneous tissue of mixed echogenicity (Fig. 19). 5,6 Discrete masses may also be seen. 5,6 Other tumor types have been reported, including squamous cell carcinoma, melanoma, and hemangiosarcoma, 5,22,25 but cannot be differentiated by their ultrasonographic appearance alone (Fig. 20). Interventional procedures such as biopsy or aspirate are required to differentiate between tumor types and to rule out infectious or inflammatory causes.

Horses presenting with hemoabdomen should be carefully evaluated for evidence of splenic hematoma and/or splenic fracture. 23,24 Splenic hematomas can appear as small to large, irregularly shaped hypoechoic areas, similar to other disorders such as splenic abscessation or even neoplasia. Careful
consideration of the complete clinical picture is important to prioritize differentials. Hypoechoic areas may also be seen in horses with splenic abscessation caused by *C. pseudotuberculosis* (Fig. 21) or other infectious agents. Similar to hepatic *C. pseudotuberculosis* abscessation, splenic abscesses often lack a visible capsule. This can create confusion for less experienced imagers who often expect to see a well-defined capsule in horses with abscessation. Ultrasound-guided aspiration is highly useful for pathogen identification and selection of appropriate antimicrobial therapy. Ultrasonographic resolution of splenic abscesses appears to be more prolonged in our experience (3 to 4 months in some horses), compared with liver and renal abscesses. Migrating foreign bodies such as ingested wires may also cause splenic abscessation (Fig. 22). The presence of hyperechoic gas echoes within splenic abscesses should heighten suspicion for wire migration, especially when located in close proximity to the stomach. Abdominal radiographs are indicated to either confirm or identify a wire as the source of abscessation.

Ultrason-Guided Procedures

As stated earlier, dramatic ultrasonographic abnormalities may be present in horses without blood work abnormalities specific to that organ. The converse may also be true. In either case, ultrasound-guided biopsy should be performed in horses with a high index of suspicion for hepatic, renal, or splenic disease regardless of the source of information (clinical, hematologic, or ultrasonographic). Ultrasound guidance allows accurate needle placement into affected regions and increases the likelihood of a diagnostic sample. It also prevents inadvertent entry into major blood vessels and abdominal viscera compared with blind sampling techniques. Automatic biopsy instruments are preferable. Biopsy needle guides may be used, but they are expensive and do not necessarily guarantee needle visibility. Free-hand ultrasound-guided techniques can be mastered with practice and provide the ultrasonographer with the most flexibility throughout the procedure. The use of anatomic landmarks as the sole means to collect samples from abdominal organs should not be used. Such techniques place the horse at increased risk for penetration of bowel or neighboring structures due to significant variability in the location and thickness of abdominal organs. Ultrasound-guided sampling is generally considered the standard of care at referral institutions.

Biopsies and aspirations of the liver, kidneys, and spleen are performed at our hospital on a routine basis to differentiate between various infectious, inflammatory, and neoplastic pathologies that may appear similarly on ultrasound examinations. Clotting profiles are often obtained before sampling to reduce the risk of postprocedural hemorrhage, although this has been infrequently reported in horses. All procedures are performed using sterile technique, including sterile skin preparation and sterile gloving of the transducer’s and ultrasonographer’s hands. The ideal site for biopsy or aspirate is identified that will maximize acquisition of a diagnostic sample while avoiding vital structures. This varies from horse to horse and depends on the location of visible pathology. Wite-Out® is useful to mark the skin surface to aid in re-identification of the intended collection site after skin preparation. A skin block is used in the majority of cases. The most important aspect of sampling is for the needle to remain within the ultrasound beam from skin to target. This is best accomplished when the ultrasonographer guides both the transducer and the biopsy instrument (Fig. 23, A and B). It is equally important to consider the “throw” of the
needle so that adjacent structures are not inadvertently penetrated by the biopsy needle during sample acquisition (Fig. 23, C and D). We generally collect two biopsy samples and submit one for histopathologic analysis and one for culture and sensitivity. Culture and sensitivity results should be used to guide antimicrobial selection.

2. Summary
Abdominal ultrasound has been extremely rewarding at our hospital to assist in the diagnosis of multiple disorders of abdominal organs and the gastrointestinal tract, covered in the previous sessions. In some horses, abnormalities are straightforward and readily detectable by veterinarians with some abdominal ultrasound experience, whereas other disorders produce more subtle findings and require the trained eye of a veteran ultrasonographer well versed in the nuances of abdominal imaging. In either situation, the use of ultrasound has transformed how we diagnose, treat, and manage horses that present with a wide variety of clinical signs.

References
13. Draper AC, Bowen IM, Hallowell GD. Reference ranges and reliability of transabdominal ultrasonographic renal dimen-

Fig. 23. A, Sterile technique to obtain a splenic biopsy. After sterile skin preparation, the transducer’s and ultrasonographer’s hands are steriley gloved. Although an assistant is used to steady and fire the biopsy instrument, the ultrasonographer is responsible for guiding the needle so that it remains within the ultrasound beam (B) to guarantee needle visibility. C, The needle (arrowheads) is visible near the hypoechoic splenic nodule (arrows) but is positioned to account for the 2-cm “throw” of the needle so that the nodule is sampled (D) while simultaneously preventing sampling of the nearby left kidney (LK).