How to Evaluate the Foal Abdomen and Thorax Ultrasonographically in the Field

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1. Introduction
As technology improves, portable ultrasonography machines continue to become more affordable and more readily available. Ultrasonography is a safe and noninvasive diagnostic imaging modality. While ultrasonographic examination of the reproductive tract has become routine, this imaging modality is often underutilized in evaluation of the horse’s two largest body cavities. Unfamiliarity with internal anatomy and interpretation of collected images can seem daunting. However, with repetition, discernment between normal and abnormal findings becomes readily achievable using equipment that a practitioner often already owns. Because ultrasonography is limited by the depth that sound waves penetrate, the relatively smaller size of foals facilitates a more complete evaluation of the abdominal and thoracic viscera compared to their older and larger counterparts. Moreover, diseases affecting the respiratory, gastrointestinal, and urogenital tracts rank among the most common causes of morbidity and mortality for neonatal and juvenile foals. Skillful employment of the ultrasound probe will speed up the diagnostic process, lending to sooner and more targeted therapeutic intervention.

2. Materials and Methods
Prior to beginning an ultrasonographic examination, there are four recommendations that should be heeded to ensure a successful study. These recommendations include examination setting, physical and chemical restraint, selection of an appropriate ultrasonographic probe, and use of a conductive medium. First, the examination should ideally take place in a quiet and dimly lit environment to allow the practitioner to effectively view the ultrasonography machine’s display screen. Second, adequate restraint of the foal should be pursued whenever possible. In the author’s opinion, ultrasonography is best accomplished in the standing foal. Thoroughly imaging a down foal requires repositioning, decreasing the efficiency of the scan compared to performing the study in a tractable standing foal. Restraint can be accomplished by one or two assistants. It is less stressful for the foal and advantageous for the restrainer to place a hand cranial to the opposite shoulders and scapula rather than across the ventral aspect of the neck (Fig. 1). If the foal’s disposition requires chemical restraint, diazepam (0.1 mg/kg, IV) with or without butorphanol tartrate (0.02–0.04 mg/kg, IV) is recommended for sick foals less than 30 days of age and for all foals less than 14 days of age. Incorporation of butorphanol might induce recumbency. For older foals, xylazine (0.3–0.5 mg/kg, IV) will likely be more effective to sedate the patient for proper examination. Third, selection of an appropriate ultrasonographic probe is critical to completing an effective examination. In the author’s opinion, a small curvilinear, or microconvex, probe is
most appropriate to evaluate the neonatal or juvenile thorax and abdomen (Fig. 2). The microconvex probe’s higher frequency range allows increased imaging detail in relatively superficial planes. The microconvex probe can reliably penetrate up to 8 to 10 cm deep. The probe’s smaller footprint fits best in the intercostal spaces of young foals. While rectal probes and linear probes generally provide an even higher frequency range, their limited penetrative abilities can compromise assessment of deeper structures. Conversely, these probes provide excellent detail with a more suitable footprint for ultrasonographic evaluation of rib fractures in neonatal foals. A linear probe or microconvex probe is most suitable for evaluation of the umbilical remnants. The large curvilinear, or macroconvex, probe is limited by its lower frequency range and larger footprint. The depths to which this probe can image (up to 30 cm) are often not required during the first few months of a foal’s life. While the microconvex probe is ideal, any of these probes is appropriate, but the practitioner should be cognizant of the limitations of each. Most ultrasonographic probes have a ridge or LED light on one side of the transducer (Fig. 3). This indicator corresponds to the indicator on the display screen (Fig. 4). Depending on the plane that is being scanned, the indicator should be pointed either laterally, cranially, or dorsally. Lastly, because ultrasonographic waves do not travel readily through air, some sort of conductive medium is required during the examination to create a seal between the skin and the ultrasound transducer. In the author’s opinion, application of isopropyl alcohol to a foal’s coat, either directly or via a soaked cotton gauze pad, provides suitable images without requiring clipping. Some practitioners prefer to clip the coat, use ultrasonographic coupling gel, or both.
Ultrasonographic Examination of the Foal Thorax

In contrast to examination of the abdominal cavity, ultrasonographic evaluation of the thoracic cavity is comparatively simple due to the low acoustic impedance of air as compared to soft tissue and viscera. Specifically, with a normal aerated lung, only the visceral pleural surface is readily imaged. It should appear as a linear hyperechoic structure that glides easily along the parietal pleural surface during the respiratory cycle (Fig. 5). Disruptions of the visceral pleural surface are indicative of pulmonary disease. The author prefers to ultrasonographically evaluate the thorax in a caudal-to-cranial direction, starting dorsally in the most caudal intercostal space in which pulmonary tissue can be identified. The probe should be moved ventrally along each intercostal space until abdominal viscera are imaged. The probe should then be moved dorsally to the next intercostal space cranially; this should be repeated until the most cranial extent of the thoracic cavity is reached. It is generally recommended to decrease the depth of the ultrasonographic field during the thoracic examination as tissue deep to the pleural surface cannot be imaged in aerated tissue due to reverberation artifact. It is important to ensure that the pleural surfaces cranial to the heart (approximately third and fourth intercostal spaces) are imaged by placing the transducer in a frontal plane over the triceps muscles (Fig. 6). It becomes necessary to considerably increase the depth of the ultrasonographic field to assess the thoracic cavity in this region. The most common pulmonary pathologies identified by ultrasonography include comet tail artifacts, pulmonary consolidation, pulmonary abscessation, and pleural effusion. Comet tail artifacts indicate roughened regions of the visceral pleural surface and are indicative of current or previous pulmonary pathology (Fig. 7). While small numbers of comet tail artifacts can be identified in normal foals, coalescing comet tail artifacts are usually indicative of more severe pathology. Coalescing comet tail artifacts might be seen in foals with meconium aspiration pneumonia or interstitial pneumonia. Although ultrasonography cannot definitively diagnose either of these disease processes, these ultrasonographic findings should prompt further diagnostic efforts, such as clinical laboratory work, thoracic radiography, lower airway endoscopy, and tracheal wash, to identify the nature of pulmonary disease. Pulmonary consolidation allows the imaging of deeper pulmonary tissue due to the absence of air in the foal’s lower airways. It should be remembered that any air prevents ultrasonographic waves from penetrating more deeply, so partially aerated tissue may incompletely obscure deeper pulmonary consolidation. Consolidated tissue may therefore only be visible during certain phases of the respiratory cycle. Completely atelectatic pulmonary...

Fig. 5. Visceral pleural surface in a normal foal.

Fig. 6. Placement of an ultrasonographic probe over the left triceps muscle to evaluate the cranial lung fields.
parenchyma is more readily imaged due to the absence of air and is often described as “hepatized” due to its resemblance to the ultrasonographic appearance of the liver and increased conspicuity of the pulmonary vasculature (Fig. 8). Pulmonary consolidation is never considered normal. In most cases, pulmonary consolidation is indicative of pneumonia. If mild with a predominantly subpleural distribution, pulmonary consolidation might be related to decreased surfactant production in neonatal foals. Additionally, pneumothorax may cause lung collapse, leading to atelectasis. While some causes of pulmonary consolidation can be excluded based on history and signalment alone, the presence of this finding is most often indicative of pneumonia or, at the very least, compromised pulmonary tissue that is susceptible to infection. Pulmonary abscesses can be difficult to distinguish from pulmonary consolidation in many instances. Often the distinction is not critical as both findings are suggestive of a lower airway infection. Only superficial abscesses can be imaged unless overlying pulmonary parenchyma is not aerated. Pulmonary abscesses caused by Rhodococcus equi are often rounded, contain anechoic or hypoechoic debris, and are surrounded by a hyperechoic rim (Fig. 9). Identification of pulmonary abscesses in foals susceptible to clinical or subclinical Rhodococcus equi pneumonia (1–6 months of age) should prompt tracheal wash for confirmatory diagnosis. On breeding farms with endemic rhodococcosis, it has been demonstrated that the majority of foals with subclinical R. equi infection will experience resolution of disease without therapeutic intervention.\(^1\) A scoring system incorporating ultrasonographic findings has been developed to better differentiate affected foals that may require therapy. The reader is directed to the references for further information on this topic.\(^2\) Pleural effusion refers to the accumulation of fluid in the pleural space. Pleuropneumonia is considerably less common in juveniles compared to adults but is observed...
occasionally. Free fluid in the thorax is often anechoic. Echogenic pleural effusion should heighten concern of an exudate (Fig. 10). A swirling appearance of the effusion may be seen in cases of hemothorax that, in neonatal foals, would be observed most frequently in instances of rib fractures. Pleural effusion will induce atelectasis of ventral pulmonary parenchyma. Unless hemothorax is strongly suspected, thoracocentesis with fluid analysis, cytology, and culture would be the most logical next diagnostic step to assess the nature of observed pleural effusion.

Ultrasonographic Evaluation of the Foal Abdomen

The principles guiding ultrasonographic evaluation of the foal's abdominal cavity do not deviate significantly from the examination of the adult abdomen. Examination of the abdomen is best described by breaking the cavity down into three regions: the left flank, the right flank, and the ventrum. Ultrasonographic examination of the left flank is best initiated caudodorsally in the left paralumbar fossa. The transducer should be oriented in a frontal plane and glided ventrally along the flank. This should be repeated in progressively more cranial planes while remaining ventral to the rib cage. In the normal foal, the spleen and left kidney should be readily imaged in the left paralumbar fossa. Along the ventral half of the left flank, the left dorsal and left ventral colon can be imaged. Normally, colonic contents include gas in addition to solid and liquid feed, so a reverberation artifact is expected deep to the colon wall. Purely liquid colonic digesta supports a diagnosis of enterocolitis. The colonic wall thickness can and should be measured in this location; normal wall thickness is less than that of an adult (2–3 mm). Following examination of the left paralumbar fossa and ventral flank, the intercostal spaces should be scanned in a caudal-to-cranial direction until no abdominal viscera can be identified, which usually occurs near the point of the elbow. Of primary importance in this region is identification of the stomach. The stomach can be recognized by its hypoechoic wall; normal wall thickness is 2 to 4 mm. The stomach is situated dorsal and slightly medial to the hilus of the spleen and typically does not extend further caudally than the 10th to 11th intercostal spaces. While the stomach might extend even further caudally immediately following nursing, a stomach distended with liquid contents in a colicky foal is an indication for immediate nasogastric intubation and decompression (Fig. 11). Lastly, a small segment of the liver can be imaged in the left cranialateral abdomen near the sixth to seventh intercostal spaces. In this location, the liver borders the spleen. This serves as a convenient site for comparing echogenicity of both viscera. In the normal foal, hepatic parenchyma should be hypoechoic compared to the spleen. To evaluate the right flank ultrasonographically, the same technique that is used on the left flank should be employed. In the caudodorsal right paralumbar fossa, the cecum can be imaged; as with the large colon, the cecum generally contains some gas, obscuring assessment of its contents. The right dorsal and right ventral colon can be identified in the ventral half of the right flank; assessment is similar to that of the left colon. The right kidney is imaged in the craniodorsal paralumbar fossa or at the 16th to 17th intercostal spaces. The right kidney serves as a helpful landmark for locating a cross-section of the duodenum, which is located just cranioventrally from the right kidney. The duodenum should be assessed for motility and wall thickness (2–3 mm). The duodenal lumen may dilate considerably with normal motility but should collapse frequently as peristaltic waves pass (Fig. 12). Turgid distension of the duodenum (greater than 2–3 cm internal diameter) is indicative of a functional or mechanical intestinal obstruction (Fig. 13). Marked thickening (>5 mm) of the duodenal wall might be identified in juvenile foals affected with impaired gastric emptying caused by...
gastroduodenal ulceration (Fig. 14). The presence of hyperechoic echoes in the bowel wall indicates intramural gas and is defined as pneumatosis intestinalis. This finding should heighten the practitioner’s suspicion of necrotizing enterocolitis. The liver is best studied along the ventral intercostal spaces of the right flank. The liver should be assessed for appropriate echogenicity and echotecture; the walls of the portal vasculature should be hyperechoic relative to the hepatic parenchyma, and the liver margins should be sharp, not extending beyond the costochondral junctions. Ultrasonographic examination of the ventrum, including the inguinal areas, is critical as identification of free peritoneal fluid and fluid-filled distended bowel is most frequently identified in this location. Evaluation of the foal’s ventrum is best accomplished by placing the ultrasound transducer in a transverse plane in the left cranioventral abdomen. The transducer should be moved in a cranial-to-caudal direction toward the pelvic inlet. This should be repeated in rightward planes until the entirety of the ventral abdomen has been examined. In the ventral abdomen, the practitioner should be able to identify the left and right ventral colons. Small intestinal loops are frequently identified in the ventral abdomen and inguinal regions; assessment of small intestinal loops in this area is identical to assessment of the duodenum (Fig. 15). Certain small intestinal abnormalities may heighten concern of a mechanical obstruction. These include the classic “target” lesion characteristic of intussusceptions or the presence of “two populations” of bowel in which some small intestinal loops are amotile and distended while other loops remain collapsed and devoid of ingesta. It has been demonstrated that intussusceptions may be identified incidentally in
an umbilical infection include enlargement of the internal structures or the presence of sedimented material or gas in the internal structures (Fig. 17). Importantly, a normal external umbilical remnant does not preclude the possibility for severe internal umbilical remnant infection. During the first week of life, the internal umbilical remnant diameter should be less than 24 mm, and the umbilical vein diameter should be less than 10 mm. The internal remnants should gradually regress and should be difficult to detect by 5 to 6 weeks of age.

3. Discussion

Ultrasonographic findings from the thorax and abdomen can provide the practitioner with a considerable amount of information when confronted with a sick foal in a stall-side setting. While ultrasonographic assessment is complex and requires skill and practice, approaching each examination in a methodical and consistent order should allow the practitioner to gain comfort in interpretation of images and differentiation between normal and abnormal. The reader is directed to the references for additional information on collection and interpretation of ultrasonographic images.

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