Review of Ultrasonographic Techniques to Improve Musculoskeletal Image Quality

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The use of ultrasound to diagnose musculoskeletal injuries in horses has become widespread. Veterinarians are being asked to evaluate multiple regions in the horse, some of which have complex anatomy and are inherently difficult to ultrasound. The production of high-quality diagnostic images can be a challenge, especially for veterinarians that did not have significant instruction in basic ultrasound technique in veterinary school. When armed with the ability to recognize common scanning errors and the skills to correct them, veterinarians can dramatically improve ultrasonographic image quality as well as their diagnostic accuracy. These skills can be applied to any tendon or ligament, regardless of the region or joint being evaluated. Author’s address: Department of Surgical & Radiological Sciences, School of Veterinary Medicine, University of California, One Shields Avenue, Davis, California 95616; e-mail: mbwhitcomb@ucdavis.edu. © 2009 AAEP.

1. Introduction

Ultrasound has been used for equine musculoskeletal imaging since the 1980s, when it was primarily used to diagnose superficial digital flexor tendonitis in racehorses. Since that time, ultrasound has gained worldwide acceptance as a diagnostic tool for musculoskeletal injuries in nearly any region of the horse. The use of ultrasound to evaluate many structures and joints has been described, and injuries have been well documented.1–28 Equine veterinarians have also benefitted from dramatic improvements in ultrasound equipment over the past decade, both in image quality and portability. Ambulatory practitioners are now able to produce images with portable machines that are similar in quality to those obtained with large, non-portable console units. Owners have also come to expect that veterinarians will able to evaluate most regions ultrasonographically with little understanding of the degree of technical skills required for such exams. Although magnetic resonance imaging (MRI) has become available for equine use, ultrasound is still routinely used to diagnose musculoskeletal injuries in many clinics because of the relative high cost of MRI, its lack of widespread availability, and its inability to evaluate all regions of the horse.

Despite these facts, it is somewhat surprising that few veterinary schools offer significant formal training in large animal (LA) ultrasonography. As such, many veterinarians and new graduates are not prepared to perform ultrasound as they enter private practice. The reasons for this deficiency are numerous. The primary reason is that there are few veterinarians with advanced formal training in LA ultrasonography. LA ultrasound remains a specialized area that has not been formally recognized or assimilated into the formal training of any other related residency program. As a result, few veterinary teaching hospitals have a dedicated service that specifically provides clinical training to fourth-year students.
year veterinary students. Many students are taught the value of ultrasound as they rotate through other services, such as lameness, surgery, or medicine; however, they may not be taught basic principles, because these services must serve multiple functions. The outcome is that many veterinarians graduate without a solid foundation of ultrasound principles and technique.

The response of veterinarians has been to participate in continuing education courses to acquire skills in ultrasonography. These courses typically focus on specific regions of the horse, partly because of participant demand and partly because of tradition. Although such courses are valuable and help fill the void in ultrasound education, they often do not teach the importance of transducer control and manipulation or the techniques required to correct an inadequate image. Some veterinarians have excellent spatial reasoning abilities and will naturally acquire these skills, but many struggle without appropriate instruction in the specific techniques to obtain high-quality images. An increasing number of veterinarians own ultrasound machines that are capable of excellent musculoskeletal imaging. It is the author’s opinion that the profession has reached a point where we must elevate our standards in regard to ultrasonographic image quality, similar to the standards that were established and are now accepted for radiographic image quality.

The purpose of this presentation is to give veterinarians the skills to improve the diagnostic quality of their ultrasound images. The focus will be on the recognition of common scanning errors and the steps required to correct them. These principles can then be applied while scanning any musculoskeletal region of the horse, regardless of the tendon or ligament being evaluated.

2. General Ultrasonographic Technique Errors

Machine Settings—Gain, Depth, and Focal Zones

Excessive gain results in a bright image. Inadequate gain results in a dark image. Although inappropriate gain is becoming a less common error, it still does occur. Excessive or inadequate gain should be considered the equivalent of a severely underexposed or overexposed radiograph, respectively. Injuries could easily be under- or over-interpreted with inappropriate gain settings. Nearly all machines have gain controls that should be adjusted to produce an image of appropriate brightness.

Excessive scanning depth is also a problem that can contribute to the misdiagnosis of injuries. As scanning depth is increased, structures appear smaller on the screen. As structures become smaller, the ability to detect small injuries is impaired. In general, a scanning depth of 4–5 cm is appropriate for the majority of musculoskeletal imaging in the limbs of horses. Metacarpal or metatarsal imaging in a large horse may require an increased scanning depth of 6–7 cm to adequately evaluate the suspensory ligament body.

The ability to move focal zones is present on nearly all machines. The location of focal zones can be determined based on the position of small triangles near the side of the ultrasound image. Most presets for musculoskeletal imaging automatically place the focal zones into the near field. This is appropriate for the majority of musculoskeletal imaging, but it must be changed when scanning deeper structures. The most common error in focal zone placement occurs during evaluation of the suspensory ligament body when the focal zones must be moved into the far field to visualize this structure adequately (Fig. 1). Evaluation of the suspensory ligament body with inappropriate focal zone placement in the near field often results in hypoechoic areas that can be easily mistaken for injury.

Transducer Orientation

All transducers have an indicator mark to indicate laterality, proximal versus distal, etc. The mark on the transducer may be a small light, ridge, or raised dot. The physical orientation of this indicator while scanning corresponds to the indicator on the

Fig. 1. Transverse ultrasonographic images of the proximal metacarpus showing (A) inappropriate and (B) appropriate machine settings to evaluate the suspensory ligament body. In A, the focal zones (two small triangles to the right of image) are located in the near field. This is appropriate for evaluation of the flexor tendons but does not result in a diagnostic image of the suspensory ligament. In B, the focal zones have been moved to the far field, resulting in an improved image of the suspensory ligament. In addition, transducer frequency was decreased from 13 to 10 MHz to maximize visualization of the suspensory ligament body. (SDFT, superficial digital flexor tendon; DDFT, deep digital flexor tendon; ICL, inferior check ligament.)
ultrasound image. For example, if the transducer indicator is positioned laterally while scanning the metacarpus, the side of the image closest to the indicator on the screen represents the lateral aspect of metacarpal structures. This can be of value if a questionable area is seen on the lateral aspect of the superficial digital flexor tendon. The transducer can then be moved in a slight lateral direction to better visualize this area.

There is no uniform consensus regarding proper transducer orientation; however, training programs in the United States instruct their trainees to hold the transducer with the indicator positioned laterally during transverse scans, proximally during longitudinal scans, and dorsally when scanning from the medial or lateral aspects of the limb (i.e., suspensory branches). To progress toward an uniform orientation, the author encourages practitioners to adopt this practice. Whether or not this technique is used, all practitioners should choose a consistent transducer orientation and use it for all exams. This will allow the ultrasonographer to more rapidly correct scanning errors solely by watching the screen. Such movements will eventually become routine and nearly automatic.

Holding the Transducer for Musculoskeletal Imaging

Transducer control is optimized by holding the transducer as shown in Figure 2A for transverse imaging and Figure 2B for longitudinal imaging. This position allows the examiner to generate the pressure necessary to evaluate most musculoskeletal regions while simultaneously maximizing transducer control and minimizing wrist strain. The middle, fourth, and fifth fingers hold the transducer while the index finger and thumb extend forward to stabilize the standoff and to maintain contact with the horse’s limb. The extended finger and thumb serve multiple functions, most importantly to stabilize the transducer. This is especially helpful when scanning regions where it is easy to “fall off” structures (e.g., during longitudinal imaging of the palmar metacarpus). The examiner should resist the temptation to pull the standoff onto the transducer. This invariably results in the standoff popping off the transducer. Instead, the transducer should be pushed into the standoff while scanning to maintain adequate contact. The digital contact with the horse also provides some insight into the horse during the scanning process when attention is focused on the ultrasound machine and away from the horse itself. This contact provides some warning if the horse is leaning, about to pick up the leg, becoming nervous, etc.

Transducer Manipulation

Skilled ultrasonographers know that the wrist must be loose and supple while scanning. This is often a difficult concept to grasp for both beginning and experienced imagers. The tendency of some veterinarians is to allow the wrist to become rigid and push as hard as possible into the horse. If the transducer cannot be placed at the appropriate angle because of wrist rigidity, no amount of pressure will produce a diagnostic image. It is possible to generate substantial transducer pressure while keeping a supple wrist.

3. Common Scanning Errors

Inappropriate Angle of Interrogation—“Off Beam”

Most imagers understand that the transducer must be held exactly perpendicular to the tendon or ligament of interest to obtain a diagnostic transverse image. It can be challenging to maintain this orientation while scanning the entire length of a structure. This is especially true when evaluating a new or difficult region. The tendency is to focus solely on getting from point A (origin) to point B (insertion). Most are able to begin with a diagnostic image, but when a slightly “off-beam” image is produced (Fig. 3A), the temptation is to continue down the structure in hopes that the image will improve. After a partially “off-beam” image is created, distal movement should stop so that the angle

Fig. 2. Techniques to hold a high-frequency linear format (tendon) transducer for (A) transverse and (B) longitudinal musculoskeletal imaging. The position of the hand on top of the transducer keeps the wrist in a comfortable position but allows it to flex and extend as necessary. The thumb and index finger stabilize the standoff but do not pull the standoff back onto the transducer. The extended index finger is able to contact the horse to improve transducer stability while scanning, and it maintains contact with the horse.
of interrogation can be corrected (Fig. 3B). After it is corrected, distal movement can proceed with the examiner stopping to correct whenever necessary. Not only can a partially “off-beam” image cause an injury to be missed, it can also create the appearance of an injury that does not exist.

Centering the Image
The structure of interest should be kept in the center of the ultrasound image throughout the entire scan of that structure. A common error is to begin with the structure in the center of the image but allow it to move gradually off the screen (Fig. 4). Doing so may cause a medial or lateral lesion to be missed if that part of the structure is off the screen. The ability to center the image helps to develop transducer manipulation skills so that the transducer can be intentionally moved to focus on any area of the image.

Inadequate Proximal to Distal Transducer Pressure
To properly evaluate fiber pattern during longitudinal imaging, the transducer must be parallel to the fibers of the tendon or ligament. When the distance of the transducer from the tendon or ligament is equal at both sides of the ultrasound image, fiber pattern is best represented (Fig. 5). When too much (or too little) pressure is applied at one end of the transducer, the structure of interest will appear to be heading “uphill” or “downhill” relative to the top of the ultrasound image. The examiner must next consider transducer orientation in relation to the horse to correct the image. If the distance from the top of the ultrasound image to the tendon/ligament is greater on the right (or proximal portion of the image), the image will appear as shown in Figure 6A. This is corrected by increasing the pressure on the proximal portion of the transducer. If the opposite is true (Fig. 6B), then increased pressure on the distal portion of the transducer is required to correct the image.

Transducer Twisting
This is a common error that occurs when the transducer is not oriented along the longitudinal axis of the tendon or ligament. It is recognized by fibers not extending fully across the width of the ultrasound image (Fig. 7A). Because some fibers are visible, examiners may incorrectly assume that image quality is adequate, but this error may cause
abnormal fiber pattern to go unnoticed. This error is readily corrected by first recognizing its appearance on the screen and then twisting the transducer slightly until fibers are seen to extend fully across the width of the ultrasound image (Fig. 7B). If the transducer is twisted in the wrong direction, the structure will begin to assume a transverse appearance. Twisting does require a steady hand for the transducer to remain centered on the tendon or ligament as it is twisted. If this technique is practiced briefly during each exam, it can be readily mastered.

Falling Off Structures
Falling off structures occurs commonly during longitudinal imaging, most often when evaluating the palmar metacarpus, plantar metatarsus, suspensory ligament branches, or patellar ligaments. When evaluating the palmar (plantar) aspect of the metacarpus or metatarsus, transducer placement for longitudinal imaging is relatively straightforward, but slipping off occurs frequently, especially when the thumb and index finger are not in contact with the horse. In any case, it is clear where to replace the transducer in this region of the horse. This is not the case for other structures. Although the suspensory ligament branches are readily visible from the medial and lateral aspects of the limb (Fig. 8A), they are taut structures; therefore, it is easy for the transducer to slip to either side of the branch (Fig. 8, B and C). If the transducer slides
dorsally, an image of the fetlock joint capsule, third metacarpal, or splint bone will be produced. If the transducer slides palmarly, an image of the digital sheath and/or vascular structures will be seen. Rather than remove the transducer from the limb and attempt to relocate the branch, the examiner can simply slide the transducer dorsally or palmarly until an image of the suspensory branch is recreated. The same principle applies when evaluating the middle patellar ligament of the stifle. This is also a taut structure but has soft infrapatellar fat on either side. As such, it is very easy for the transducer to fall to either side of the ligament, resulting in an image of fat. To correct this, the examiner can slide the transducer medially or laterally to reproduce an image of the ligament. This technique can also be practiced by intentionally falling off these ligaments and then sliding the transducer appropriately to reproduce a diagnostic image. This should be practiced while watching the ultrasound screen and not by looking directly at the horse.

4. Discussion
The techniques described are the culmination of 10 yr of experience teaching veterinary students and veterinarians how to perform ultrasound exams. Surprisingly, the importance of teaching these techniques did not become readily apparent until the past 2–3 yr. In keeping with demand, the author began teaching ultrasonography with the objective of teaching region by region and structure by structure rather than focusing on the transducer manipulation skills that enable veterinarians to obtain a high-quality image regardless of the region being scanned. As overall skill level, anatomical knowledge, and ability to recognize injuries has improved over the years, it is time to focus on raising our standards for ultrasound image quality. For these reasons, the author has begun to change focus when instructing veterinary students and veterinarians in the art of ultrasonography. When armed with the tools to recognize and correct the imaging errors described above, veterinarians are fortified with the skills to create diagnostic images of the majority of tendon and ligaments in the horse.

In fact, the author encourages the intentional creation of these errors while scanning so that the techniques to correct them can be mastered with practice. Doing so gives the examiner the confidence to correct scanning errors when they occur unintentionally. These “errors” do not discriminate. They occur regardless of the skill level of the examiner. A slight shift in weight or swaying of the horse can cause any examiner to fall off structures or create a twisted image. Because these “errors” are rapidly corrected by skilled ultrasonographers, it may appear that they never occur during their scans.

In summary, most veterinarians can read or learn to read a high-quality ultrasonographic image of nearly any structure, but the skills required to obtain a diagnostic-quality ultrasound image are much more difficult to master. Unfortunately, there is no substitute for practice and experience to develop proper technique and transducer manipulation skills. When coupled with an excellent knowledge of anatomy, high-quality diagnostic images can be obtained of any region or joint in the horse.

References


