How to Perform Plantar Non-Weight-Bearing Ultrasonographic Evaluation of the Equine Hind Proximal Suspensory Ligament

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1. Introduction

Suspensory ligament injury is an important source of lameness or poor performance in athletic horses. As injury to the suspensory ligament can affect the ligament and third metatarsal bone, ultrasonography is commonly used to evaluate the suspensory ligament and may be a reasonably accurate predictor of suspensory ligament pathology. An accurate diagnosis of proximal suspensory desmopathy is of great importance as recommended options for management can be expensive and lengthy. Regions of fat and muscle create variations in the suspensory ligament's echogenicity. This echo pattern makes it difficult to determine if these variations in echogenicity are the result of injury or normal suspensory ligament anatomy. In order to identify regions of suspensory ligament fibers versus areas of fat and muscle, off-angle or oblique-incidence imaging should be performed. When using off-angle imaging, the position of the probe is changed such that the ultrasound beam is no longer perpendicular to the longitudinal axis of the suspensory ligament fibers. This change in the position of the probe, and the resulting change in the echogenicity of suspensory ligament fibers and that of the regions of fat and muscle, can be used to identify the regions of different tissue types within the ligament. When the ultrasound beam is perpendicular to the longitudinal axis of linear fibers within a normal tendon or ligament, maximum echogenicity is created. However, the difference between the echogenicity of fat and muscle cannot be readily identified in the suspensory ligament. Therefore, comparing the appearance of the suspensory ligament with the beam both perpendicular (on angle) and not perpendicular (off angle) to the ligament allows identification of fibers versus regions of fat and muscle. Regions of mottling or decreased echogenicity identified in the suspensory ligament with ultrasound can then be further investigated using changes in beam angle to determine if the source of these regions is ligament fibers or fat.
and muscle. This paper describes the ultrasonographic method of evaluating the equine proximal hind suspensory ligament using the plantar non-weight-bearing approach using on- and off-angle imaging as compared to the standard method.

2. Materials and Methods

Patient Preparation and Positioning

The hair should be clipped on the plantar aspect of the metatarsal region beginning just proximal to the chestnut. Beginning at the level of the chestnut, the skin should be clipped over the plantar and plantaromedial aspects of the metatarsus extending distally to the level of the suspensory ligament bifurcation. Following clipping, the skin should be cleansed and coupling gel liberally applied. When evaluating the hind suspensory ligament with ultrasound, the authors typically perform the plantaromedial approach first with the limb in a weight-bearing position, followed by the plantar non-weight-bearing approach. The plantaromedial weight-bearing approach is not described in this paper. For the plantar non-weight-bearing approach, the limb may be positioned in one of the following manners depending on the operator’s preference: (1) resting on the toe or (2) pulled forward with the foot resting on the operator’s knees; (3) the foot may be propped on a farrier stand, or (4) the foot may be held in a non-weight-bearing position by an assistant (Fig. 1). This creates laxity in the flexor tendons, resulting in a widening of the skin surface for increased probe contact, and decreases the distance between the ultrasound probe and the suspensory ligament, allowing adjustments in the ultrasound machine settings for a more detailed evaluation of the ligament.

Ultrasound Probe and Settings

High-frequency (7.5-16 MHz) linear array ultrasound probes are preferred for this examination. The frequency, focal zones, depth, and gain should be adjusted to maximize image quality at the level of the suspensory ligament. For an average-size Warmblood or Thoroughbred horse, a 4-cm depth setting and a frequency of 10 MHz are reasonable initial machine settings that can then be adjusted based on the individual patient. Although all structures at this level should be assessed during the ultrasound examination, the minimum depth should be selected that places the hyperechoic line representing the plantar third metatarsal bone margin clearly in the far field of the image.

Ultrasound Examination

First, the horse should be appropriately restrained and the limb positioned as described above, according to the operator’s preference. The ultrasound probe is placed in a transverse position on the plantar aspect of the limb, immediately distal to the tarsometatarsal joint at the level of the suspensory ligament attachment on the third metatarsal bone. The entirety of the proximal suspensory ligament is evaluated prior to evaluating the proximal branch of the suspensory ligament. This structure is also referred to as the accessory ligament or the proximal bundle in the literature. When the limb is in a non-weight-bearing position, manipulating the flexor tendons allows for ultrasound beam to be oriented dorsally as possible while still visualizing the entire ligament. This is achieved by placing the probe surface parallel to the plantar third metatarsal bone margin. The initial image created should allow visualization of the axial surfaces of the second and fourth metatarsal bones with the plantar margin of the third metatarsal bone oriented in a horizontal position. Once the initial image is obtained, the ultrasound machine settings should be adjusted from baseline to ensure the correct depth, frequency, gain, and focal zones. The time gain compensation settings should be used to create uniform echogenicity in the image, which typically requires increasing the gain in the image far field. Normal suspensory ligament fibers will be echogenic when the ultrasound beam is perpendicular to the longitudinal axis of the fibers and will become hypoechogenic when the probe position is changed such that the beam is no longer perpendicular to the fibers. Regions of fat and muscle will remain echogenic regardless of beam angle. Both on- and off-angle images are obtained during this examination, and corresponding longitudinal images can be obtained. Off-angle images of the ligament in its entirety should be obtained first, which allows
identification of anatomic features of the ligament such as size, shape, and margins as well as the fat and muscle distribution, which correlates to gross and MRI findings (Fig. 2). Off-angle images are obtained by raising or lowering the probe cable at the site of skin contact. The probe position should be changed the minimum amount that decreases the echogenicity of the ligament fibers. This has been reported as approximately 10°. These images should be saved and compared to the on-angle images in order to identify and characterize pathologic change. In order to ensure that the on- and off-angle images are obtained at the same level, minor movements in probe position are necessary. Lowering the probe cable to create an off-angle image will require distal movement of the probe to match the on-angle image at the same level. Anatomic landmarks, such as the shape of the osseous margins, are used to ensure the off- and on-angle images are made at the same level. Setting the ultrasound machine to a split screen and obtaining off-angle images and on-angle images at the same level will assist with making these comparisons. A measurement system (zones or centimeters) should be consistently used. The entire suspensory ligament from the proximal branch continuing to the distal extent of the body should be evaluated in transverse and longitudinal planes with images obtained at regular measurement intervals. The size, shape, margins, and peri-ligamentous tissues are best evaluated on off-angle images. Both on- and off-angle images should be evaluated for differences in echogenicity. When learning this technique, the proximal branch is most easily identified by placing the probe at the level of the suspensory ligament attachment on the third metatarsal bone and then following the fibers proximally to the fourth tarsal bone. Comparison images of the opposite limb are imperative in all cases. The size and shape of the fourth metatarsal bone and its relationship to the third metatarsal bone can be used to ensure comparisons between the right and left hindlimbs are being made at the same level.

3. Results

Since 2008, approximately 2000 horses have had ultrasound examination of the hind proximal suspensory ligament incorporating the plantar non-weight-bearing approach. The suspensory ligament anatomy has been well identified using this technique. In addition, suspensory ligament enlargement, fiber abnormalities, and alterations in the fat and muscle bundles have been diagnosed using this technique. Beginning the examination immediately distal to the tarsometatarsal joint, the suspensory ligament consists of a narrow, rectangular-to-square band of ligamentous fibers attached to the plantar surface of the third metatarsal bone. The fibers are more prominent lateral of midline (Fig. 3). The suspensory ligament has a relatively homogenous
echogenicity with no fat or muscle at the proximal extent of the third metatarsal bone attachment. In the distal half of the third metatarsal bone attachment, the suspensory ligament has small regions of fat and muscle, and the ligament becomes triangular in shape (Fig. 4). At this level, there is a focal bundle of ligament fibers originating from the fourth metatarsal bone that merge with the suspensory ligament. Distal to the third metatarsal bone attachment, there may be a partial sagittal cleft dorsally, giving the ligament a heart-shaped appearance (Fig. 5). However, this sagittal cleft is not present in all horses, and in the absence of a sagittal cleft, the ligament is oval distal to the third metatarsal bone attachment (Fig. 6). As the suspensory ligament continues distally from the third metatarsal bone attachment, there is typically a prominent central area of fibers (central fiber bundle) as well as peripheral fibers with regions of fat and muscle that become more prominent. In off-angle images distal to the third metatarsal bone attachment, the suspensory ligament appears separated from the third metatarsal bone plantar margin by hyperechogenic connective tissue and vessels. This is how the distal extent of the third metatarsal bone attachment can be identified. Beginning at this level and continuing distally to the level of the suspensory ligament bifurcation, there are fat and muscle bundles located within the lateral and medial fiber bundles of the suspensory ligament. The lateral fiber bundle is slightly larger than the medial fiber bundle. These medial and lateral fiber bundles are triangular to oblong in shape, oriented in a dorsoplantar direction. However, random areas of fat and muscle can dissect through the peripheral ligament margin and can become zigzag in shape in the ligament body. Asymmetry of the fat and muscle pattern can exist between limbs, and these regions should not be mistaken for injury. The suspensory ligament has a larger amount of connective tissue separating it from the second metatarsal bone when compared to the distance between the fourth metatarsal bone axial margin and the lateral aspect of the ligament. A linear region of fascial tissue is sometimes identified plantar to the suspensory ligament, running between the plantar margins of the second

Fig. 4. MRI images of the suspensory ligament, moving from proximal to distal. Ligament fibers are black and the fat and muscle bundles are intermediate to light gray on these images. A, The suspensory ligament immediately distal to the tarsometatarsal joint. The suspensory ligament is a narrow, rectangular-to-square band of ligamentous fibers attached to the plantar surface of the third metatarsal bone (arrow) with no fat or muscle. B, The suspensory ligament at the mid aspect of the third metatarsal bone attachment. Small regions of fat and muscle become visible medial and lateral to the central fiber bundle (arrow). Lateral fibers can be seen extending from the fourth metatarsal bone toward the central fiber bundle that will merge into the ligament (arrowhead). C, The suspensory ligament at the distal extent of the third metatarsal bone attachment. Prominent regions of fat and muscle are now present in the suspensory ligament, and the ligament has a triangular shape (arrow). D, Distal to the third metatarsal bone attachment, notice the partial sagittal cleft dorsally, giving the suspensory ligament a heart-shaped appearance (arrow). There is connective tissue dorsal (light gray region) to the suspensory ligament that will be echogenic regardless of beam angle, and this can be used to identify the distal extent of the attachment on transverse off-angle images. E, Continuing distally, the suspensory ligament becomes more oval (arrow) as the sagittal crest recedes.

Fig. 5. MRI image (A) with comparison on- (B, D) and off-angle (C) ultrasound images of the suspensory ligament just distal to the third metatarsal bone attachment, with approximate location of the ultrasound probe at this level (E). The MRI image has been rotated to match the ultrasound images. The on-angle ultrasound images (B, D) have minor heterogeneity in the echo pattern. The off-angle ultrasound image (C) can be used to identify the peripheral ligament margin and the regions of fat and muscle (arrows). Image C is provided without outline to evaluate where the peripheral ligaments would potentially seem to be in the absence of the off-angle image, which clearly identifies the ligament margins.
and fourth metatarsal bones. The proximal suspensory ligament branch is oval in shape and homogeneous with no fat or muscle bundles, appearing similar in echogenicity to a tendon as it extends to the fourth tarsal bone. This branch lies medial to the plantar ligament (Fig. 7). This constitutes the appearance of the suspensory ligament using the plantar non-weight-bearing approach.

4. Discussion

This technique has been incorporated into all hind-limb proximal suspensory ligament ultrasound evaluations since 2008. It provides a method for determining the different tissue types within the suspensory ligament, which allows the identification of normal anatomic characteristics versus pathologic change. The echogenicity of the connective tissue surrounding the suspensory ligament is not beam-angle dependent, remaining echogenic regardless of beam angle. This is the reason that off-angle images are most effective at defining the ligament margins, differentiating them from the surrounding echogenic connective tissue. Additionally, the limb positioning and resulting displacement of the plantar soft tissues and vasculature reduces edge artifacts, which can obscure the suspensory ligament. This technique, which can be performed in the field, provides images that are similar in appearance to MRI images and gross pathology of the suspensory ligament, reflecting the true anatomic features of the ligament (Fig. 2). Utilizing the described technique places the ultrasound beam perpendicular to the bone-ligament interface, aiding in the identification of abnormalities at the suspensory ligament attachment on the third metatarsal bone. The dorsal aspect of the ligament and the central fiber bundle are commonly affected regions, and this technique improves visualization of these specific regions. Limitations to this technique include patient compliance with positioning. However, this is a consistent finding with any ultrasound evaluation and can be assisted with proper restraint and/or sedation. An additional limitation is that an in-depth knowledge of the suspensory ligament anatomic features is required in order to effectively utilize the technique. This technique may be considered by some to be challenging; however, with practice and knowledge of normal anatomic features, it can be mastered. Due to normal anatomic variations, there is the potential for asymmetry of the fiber and fat/muscle distribution when comparing opposite limbs. However, the opposite limb still provides a helpful guide for determining the anatomic features of the ligament. In addition, fiber disruption and/or moderate fiber abnormalities are both decreased in echogenicity to anechoic regardless of beam angle, distinguishing them from normal ligament fibers or other tissue types. A thorough clinical evaluation should be performed prior to ultrasonographic

![Fig. 6. MRI (A) with comparison on- (B) and off-angle (C) ultrasound images of the suspensory ligament distal to the third metatarsal bone attachment, with approximate location of the ultrasound probe at this level (D). The MRI image has been rotated to match the ultrasound images. The on-angle ultrasound image (B) has minor heterogeneity in the echo pattern. The off-angle ultrasound image can be used to identify the regions of fat and muscle (arrows). Notice the oval shape of the suspensory ligament at this level.](image)

![Fig. 7. MRI (A) and ultrasound (B) images of the proximal branch of the suspensory ligament at the level of the fourth tarsal bone and approximate location of the ultrasound probe at this level (C). Notice the round shape of the proximal branch (outline), surrounding plantar ligament (star), superficial digital flexor tendon (arrowhead), and deep digital flexor tendon (arrow).](image)
evaluation to ensure the findings can be correlated with the clinical presentation. This technique should be incorporated into the standard suspensory ligament ultrasound examination in conjunction with the plantaromedial approach. Subtle changes in shape as a result of ligament injury are often visible before fiber abnormalities are detected. Therefore, a comparison with the opposite limb is imperative to identify these subtle ligament shape changes. In conclusion, a thorough understanding of the normal anatomy in conjunction with a complete examination as described in this manuscript and comparison to the opposite limb will provide the most clinically relevant information in regard to the condition of the suspensory ligament.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References