Review of Non-Weight-Bearing Proximal Suspensory Ligament Ultrasound for Alterations in the Muscle/Fat Indicating Pathologic Change

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Ultrasonographic evaluation of the fat and muscle in the proximal suspensory ligament, with comparison of on- and off-angle non-weight-bearing images, can provide useful information about suspensory ligament injury. Alterations in the fat and muscle distribution on ultrasound images are an important and sometimes the only indication of pathologic change. Author’s address: Equine Diagnostic Imaging, 14313 SW 79th Street, Archer, FL 32618; e-mail: equinedxim@yahoo.com. © 2021 AAEP.

1. Introduction

Proximal suspensory ligament disease is a common source of lameness in performance horses. Diagnosis of lameness localized to the proximal metacarpal or metatarsal region is typically achieved by physical examination, diagnostic analgesia, and imaging. Radiographs can be used to identify changes in bone density at the attachment of the suspensory ligament on the third metacarpal or metatarsal bone. Increased density resulting from sclerosis and/or decreased density resulting from lysis or resorption are radiographically identifiable abnormalities that can be associated with suspensory ligament injury. Ultrasound is typically used to evaluate the suspensory ligament prior to advanced imaging when lameness is localized to the proximal metacarpal and metatarsal regions. Ultrasound of the proximal suspensory ligament requires a thorough knowledge of anatomy and the normal anatomic variations of the suspensory ligament when comparing different horses as well as different limbs of the same horse. A complete ultrasound examination of the suspensory ligament has evolved over the last several years. New ultrasound methods have been developed that allow a more precise and complete evaluation of the complex suspensory ligament anatomy than can be accomplished using the standard on-angle weight-bearing technique. On- and off-angle non-weight-bearing ultrasound imaging is now considered an invaluable component of the complete proximal suspensory ligament ultrasound examination, and the advantages of this technique have been well established. This technique allows a complete evaluation of the suspensory ligament with identification of the different tissue types within the suspensory ligament. Identification of the complete suspensory ligament and the normal anatomy and the normal anatomic variations of the suspensory ligament when comparing different horses as well as different limbs of the same horse.
anatomy is an important component and the first step in the diagnosis of pathologic change.10

There are a wide range of abnormalities that can affect the proximal suspensory ligament and the third metacarpal or metatarsal bone attachment resulting in lameness. Advanced imaging, such as magnetic resonance imaging (MRI) and computed tomography (CT), has been used for the diagnosis of pathologic change in the proximal suspensory ligament and is more effective than ultrasound for diagnosing certain components of injury in this region. MRI, CT, and ultrasound identify different types of pathologic change affecting the proximal suspensory ligament and its osseous attachment. MRI excels at soft tissue detail and has been a tremendous educational tool by clearly demonstrating the normal anatomic features and variations of the suspensory ligament as well as the different types of pathologic change. CT demonstrates bone detail and vascular patterns within injury, and the use of contrast increases the conspicuity of associated soft tissue injury. Advanced imaging is necessary to identify certain types of suspensory ligament injury, and this is typically dependent on the nature and severity of the injury. However, there are specific patterns of pathologic change that in the past were not diagnosed with ultrasound initially but were identified using MRI and then retrospectively identified with ultrasound. Eventually, with practice and experience, certain types of pathologic change can be more easily identified prospectively with ultrasound when the specific patterns of injury are better understood. One specific pattern of pathologic change in the suspensory ligament that is evident on MRI and can be identified well with ultrasound involves alterations and/or abnormalities in the fat and muscle distribution. In certain cases, these alterations and/or abnormalities in the fat and muscle distribution of the suspensory ligament can be the most evident abnormality on an ultrasound examination. Abnormalities affecting the fat and muscle of the suspensory ligament are typically accompanied by fiber abnormalities and often focal or diffuse suspensory ligament enlargement. A wide range of fiber abnormalities can be present in the suspensory ligament, with various degrees of clinical relevance. Some clinically relevant fiber abnormalities do not produce a detectable change in the echo pattern of the ligament fibers when examined with ultrasound. In these cases, abnormalities of the fat and muscle and ligament enlargement can be the most evident change identified with ultrasound. This paper will review the techniques for identifying abnormalities in the fat and muscle distribution of the proximal suspensory ligament as an indication of pathologic change using the on- and off-angle non-weight-bearing ultrasound examination.

2. Methods

The palmar or plantar non-weight-bearing approach using on- and off-angle ultrasound imaging with comparison to the opposite limb is recommended for specific evaluation of the fat and muscle distribution in the suspensory ligament. Although evaluation of the fat and muscle in the suspensory ligament can be done using on- and off-angle imaging with the limb in a weight-bearing position, placing the limb in a non-weight-bearing position for this examination will yield additional information that will aid in the diagnosis of injury. Assessment of the fat and muscle is not necessary for the proximal suspensory ligament branch in the hind limb, as it does not contain fat and muscle. However, on- and off-angle imaging will still provide additional information about the proximal branch of the suspensory ligament, which is best identified with the limb in a non-weight-bearing position. In both the front and hind limbs, the non-weight-bearing off-angle technique is first used to identify the entire peripheral margin of the suspensory ligament, which is achieved when the second, third and fourth metacarpal or metatarsal bones are identified (Fig. 1). This initial assessment of the suspensory ligament should be made with the third metacarpal or metatarsal bone visible as a horizontal echogenic line at the distal extent or far field of the image. The orientation of this line is extremely important as the horizontal positioning of the third metacarpal or metatarsal bone ensures that the ultrasound beam is interacting with the fibers at the same angle allowing comparison of the echogenicity within different portions of the ligament. Although the horizontal position of the third metacarpal or metatarsal bone is considered imperative for the initial images, there are reasons to change this osseous margin orientation when specifically evaluating different structures or features of the proximal metacarpal and metatarsal regions, such as the interosseous spaces or axial surfaces of the splint bones and their relationship with the suspensory ligament margins (Fig. 2). On the initial image, once the correct positioning of the suspensory ligament is achieved in the off-angle ultrasound image, the normal anatomic features of the ligament should be identified and evaluated. This includes the ligament margins, boundaries of the medial and lateral lobes in the forelimb or fiber bundles in the hind as well as the regions of ligament fibers versus fat and muscle. The purpose of this assessment is to determine if the pattern of ligament fibers and the fat and muscle distribution represent normal anatomic variation or pathologic change. This process consists of two steps. The first is to compare the anatomic characteristics of the ligament to the opposite limb. The second is to evaluate the ultrasonographic appearance of the ligament considering the patterns of normal anatomic variation that exist within the different limbs of the same horse (Fig. 3). If pathologic change is present in the ligament, comparison of the on- and off-angle images are used to determine the nature of the pathologic change. The opposite leg can be used as a guide for determining the size, shape, margins, and overall pattern of ligament fibers versus fat and muscle.
within the suspensory ligament on the off-angle images. Certainly, horses can be bilaterally affected. However, comparison to the opposite limb remains the most useful method for attempting to determine the normal characteristics of the suspensory ligament for a specific patient. For the purposes of this paper, the comparison leg will be referred to as if it does not have pathologic change in the suspensory ligament, which the author acknowledges may not be the case in all patients. When comparing to the opposite limb, the medial and lateral aspects of the suspensory ligament should be compared at the same level and region, with great care taken to ensure the levels match. Due to the marked changes that occur in the size, shape, margins, and tissue distribution of the ligament, minor differences in the level of the ligament when comparing limbs could produce marked asymmetry as a result of positioning, which should not be mistaken for pathologic change. Osseous landmarks provide the most reliable method of ensuring comparison images are made at the same level. Pathologic change within the suspensory ligament can alter all the normal anatomic features. Alterations in the appearance of the lobe size and shape, alterations in the distribution of the fat and muscle, as well as an abnormal echo pattern can be identified with suspensory ligament injury. For the purposes of this paper, the fat and muscle will be considered to have a similar echogenicity and similar response to changes in beam angle, such that they cannot be distinguished from each other but can clearly be distinguished from ligament fibers. They will be considered a single tissue type for the purposes of this technique. Off-angle images of the affected limb should be evaluated with specific assessment of the relationship between the
suspensory ligament fibers and the fat and muscle throughout the length of the ligament. This assessment should include the echogenicity of the fibers versus the fat and muscle, the clarity of the interface between the fibers and the regions of fat and muscle, as well as the position and the size of the fat and muscle. Several different abnormalities can occur in the relationship between the fibers and the fat and muscle when pathologic change occurs in the suspensory ligament. The clarity of the interface between the fibers and the regions of fat and muscle can decrease, the fat and muscle can be decreased in size or obliterated, and the regions of fat and muscle are often displaced as a result of enlargement of the fibers (Figs. 4, 5). The clarity of the interface between the fibers and the fat and muscle is the most difficult feature to evaluate and must be assessed in light of the overall quality of the images. There is variation in the quality of the images when comparing...
different horses affecting the amount of difference in the echogenicity of the ligament fibers versus the regions of fat and muscle, which directly impacts the clarity of the interface. Once abnormalities are identified within the suspensory ligament on the off-angle images, these specific regions are then evaluated on the on-angle images to determine if there is abnormal echogenicity within the regions corresponding to ligament fibers that would indicate fiber abnormalities are present.

3. Results

Using on- and off-angle non-weight-bearing ultrasound examination, generalized suspensory ligament enlargement or specific regions of enlargement can be detected. Furthermore, alterations in the echogenicity of the fibers as well as alterations in the margins, size, shape, and position of the fat and muscle bundles can also be identified. The severity of the abnormalities identified affecting the ligament fibers as well as the fat and muscle bundles can be used to assess the degree of pathologic change in the suspensory ligament. Enlargement or an abnormal shape can be identified by rounding of specific ligament margins or the entire ligament. Normal fore and hind limb suspensory ligaments have a specific characteristic size and shape. The fore limbs have a medial lobe that is longer in its medial to lateral dimension when compared to its dorsal to palmar dimension. In contrast, the lateral lobe in the fore limb is typically markedly shorter in its medial to lateral dimension and mildly longer in its dorsal to palmar dimension when compared to the medial lobe. The hind limb suspensory ligament goes through many characteristic shape changes beginning at the third metatarsal bone attachment and continuing into the suspensory ligament body. In the hind limbs, generalized suspensory ligament enlargement causes the ligament to appear rounded at a level where it should be triangular or oval (Fig. 4). In the fore limbs, the normal palmar margin of the suspensory appears flat and will become rounded with enlargement that can typically be attributed to a specific lobe, unless both lobes are affected. Suspensory ligament enlargement impacts the relationship between the ligament margins and the surrounding connective tissue and subsequently

Fig. 4. Corresponding MRI and non-weight-bearing on- and off-angle images of right and left hind proximal suspensory ligaments in a case with right hind lameness localized to this region. The off-angle image of the right hind is duplicated so that the borders of the fat and muscle can be delineated (dashed outlines) and then compared to the unmarked image. The right hind suspensory ligament is enlarged and abnormally shaped based on the off-angle comparison images of the right and left hind. The left hind maintains a triangular plantar margin while the right hind has a rounded, wide plantar margin (white outlines). However, the most notable abnormality on the ultrasound images is the shape of the lateral fat and muscle bundle (arrows) when comparing the limbs. It is comma shaped in the right hind because it is medially displaced and compressed. There are extensive fiber abnormalities on the MRI image (arrowhead) in the lateral aspect of the suspensory ligament that do not produce a detectable change in the echo pattern of the suspensory ligament on the ultrasound images. These fiber abnormalities were only present on the proton density MRI images and not on the T2 fast spin echo or proton density fat suppressed images, which correlates with the lack of ultrasound visibility. The greatest indication of pathologic change on the ultrasound images is the alteration of the fat and muscle size and position, because the fiber abnormalities were not detectable with ultrasound. The white outlines denote the shape of the suspensory ligament margins have been moved plantar to allow visualization of the ligament margins.
the splint bones. Enlargement affecting the medial or lateral aspects of the suspensory ligament will compress the surrounding connective tissue, decreasing the distance between the ligament margins and the axial surfaces of the splint bones. Dorsal ligament enlargement will compress or obliterate the connective tissue along the dorsal ligament margin. This will change the thickness of the dorsal connective tissue or the level at which the connective tissue becomes visible dorsal to the ligament when compared to the opposite limb (Fig. 3). The most effective way to identify enlargement of the suspensory ligament immediately distal to the third metatarsal bone attachment is to create images of both limbs at the same level using the fourth metatarsal bone shape and size as a level marker, and then compare the dorsal connective tissue thickness. The affected limb will have reduced dorsal connective tissue or no dorsal connective tissue at the level where the comparison leg has dorsal connective tissue. Once a region of enlargement is identified, close evaluation of the tissues in this region should then be performed because alterations in the fat and muscle bundles often accompany focal or diffuse suspensory ligament enlargement. The size, shape, and position of the fat and muscle bundles should be evaluated compared to the opposite limb. With enlargement of the dorsal suspensory ligament fibers, which seems the most frequently affected area, there will be palmar or plantar displacement of the fat and muscle bundles. Central fiber bundle enlargement occurs frequently in the hind suspensory ligament resulting in the peripheral displacement of the fat and muscle. Palmar or plantar fiber enlargement does occur and can result in dorsal fat and muscle displacement but is the least frequently encountered displacement of the fat and muscle (Fig. 6). One characteristic of pathologic change in the suspensory ligament that is evident on MRI and can be well identified with ultrasound is displacement, decreased size or obliteration of the fat and muscle bundles. In certain cases, alterations in the fat and muscle can be the most evident or only ultrasound finding in horses with lameness resulting from suspensory ligament injury. Decreased margin clarity between the fat and muscle bundles and ligament fibers can be detected but is more technically challenging and requires high quality ultrasound images. Abnormalities in the fat and muscle

Fig. 5. Corresponding MRI and non-weight-bearing on- and off-angle images of right and left hind proximal suspensory ligaments. The dorsal margin of each suspensory ligament is denoted by an asterisk on the off-angle images. The left hind suspensory ligament is enlarged and abnormally shaped based on the off-angle comparison images of the right and left hind. It has marked dorsal enlargement with focal moderate fiber abnormalities (arrows) in the dorsal extent of the enlargement that can best be identified in the on-angle ultrasound image. The fiber abnormalities in the dorsal aspect of the suspensory ligament produce a detectable change in the echo pattern of the suspensory ligament because of their severity. These fiber abnormalities can be identified on the proton density images with and without fat suppression. The severity of the fiber abnormalities causes them to be visible on ultrasound in contrast to the fiber abnormalities in Figure 4. In addition to the fiber abnormalities, alteration in the fat and muscle can be identified in the left hind. The fat and muscle bundles are plantarly displaced and the lateral bundle has a poorly defined interface with the ligament fibers. The marked dorsal enlargement of the left hind suspensory ligament is displacing the normal dorsal vasculature. However, this is not the case in the right hind, and the vessel (arrowhead) should not be mistaken for a lesion. It is outside the ligament margins on the off-angle image and its pathway can be followed or tracked in real time imaging.
Fig. 6. MRI and US images of the right hind (A, B, C) proximal suspensory ligament with comparison images of the left hind (D, E) in the proximal metatarsal region. The right hind suspensory ligament has focal plantar enlargement that can be well identified on the MRI and off-angle ultrasound images (white outlines on A and B). The shape of the plantar margin is quite different when compared to the left hind suspensory ligament at the same level (white outlines on D and E). Within the region of plantar enlargement affecting the right hind suspensory ligament, there are focal fiber abnormalities which can be identified on the MRI image (A) and in the on-angle ultrasound image (arrow on C). The region is less commonly affected than the dorsal aspect of the ligament. However, abnormalities can occur in this region. The white outlines denoting the shape of the suspensory ligament margins have been moved plantar to allow visualization of the ligament margins.
distribution and associated regions of fiber enlargement are noted, and these regions are then specifically evaluated on the on-angle images. Within the defined regions of ligament fibers identified on the off-angle images, there should be a normal, uniform echogenic pattern on the on-angle images if no detectable fiber abnormalities are present. Areas of ligament fibers that have decreased echogenicity regardless of beam angle, on both on- and off-angle images, should be interpreted as abnormal. The severity of the fiber abnormalities is proportional to the decrease in echogenicity as compared to a region of normal fibers. However, there can be clinically relevant fiber abnormalities in the suspensory ligament that do not produce a detectable change in echogenicity on ultrasound images (Fig. 4). These fibers can have an abnormal signal pattern on MRI images that is not detectable with ultrasound. In these cases, assessment of the fat and muscle becomes paramount as it can be the only indication of pathologic change in the suspensory ligament using ultrasound. In many cases it is accompanied by focal or diffuse ligament enlargement. The lack of decreased echogenicity in the fibers does not mitigate the clinical relevance of the abnormalities in the fat and muscle distribution.

4. Discussion

Evaluation of the fat and muscle in the suspensory ligament provides important information regarding the diagnosis of pathologic change. Using this technique over time will provide a knowledge base allowing a more accurate distinction between pathologic change and anatomic variation in the suspensory ligament. Whenever possible, comparison between ultrasound images and advanced imaging such as MRI should be performed, as this will provide a better understanding of the ultrasound images. MRI clearly demonstrates the normal characteristics and variation of all the salient anatomic features within the proximal metacarpal or metatarsal regions, which can then be correlated to ultrasound images. With experience, this information leads to a more accurate assessment of ultrasound images in the absence of an MRI. In difficult cases where alterations in the fat and muscle are not detected initially with ultrasound but are evident on MRI images, it is often possible to identify these changes retrospectively on ultrasound images which can be used to monitor abnormalities over time. The subjective assessment of differences in the appearance of the suspensory ligaments when comparing the fore or hind limbs, and whether to attribute these differences to anatomic variation or pathologic change, comes from experience in imaging different horses over time. There are rare cases with marked differences when comparing opposite limbs due to anatomic variation. However, the majority of horses fall within an expected range of variation, of which some subtleties cannot be detected with ultrasound but only with MRI. Therefore, the opposite limb provides a reasonable guide during the learning process. In cases where there is not a detectable change in the echo pattern of the suspensory ligament fibers, alterations of the fat and muscle bundles can be the only ultrasound visible indication of clinically relevant pathologic change. Incorporating assessment of the fat and muscle when using the on- and off-angle non-weight-bearing ultrasound technique adds valuable information for the initial diagnosis and monitoring over time. In addition, MRI is most important in these cases to accurately characterize the injury to the suspensory ligament. There are limitations to this technique. The suspensory ligament fibers curve dorsally at their osseous attachments, and this will create variation in the echogenicity of the ligament when comparing the dorsal and palmar or plantar aspects of the ligament. The amount of curvature varies in different horses and therefore requires experience to determine anatomic variation versus pathologic change. However, in most horses this variation should be relatively uniform and mild when comparing the medial and lateral aspects of the ligament. When there is decreased echogenicity in the dorsal aspect of the suspensory ligament, the other characteristics of the ligament should be closely evaluated for other evidence that supports normal anatomic variation or pathologic change. Unfortunately, there are cases with decreased echogenicity in the dorsal aspect of the ligament that is not representative of pathologic change. However, no other evidence of injury is present, such as enlargement or alterations in the fat and muscle, and this appearance is typically bilaterally present. Therefore, comparison images are quite helpful in these cases. Another limitation of this technique is that the tissue within the suspensory ligament margins that remains echogenic regardless of beam angle can be fat and muscle or scarring. There is not a completely reliable method to distinguish fat and muscle from scarring on ultrasound images purely using the echogenicity because these tissue types will have a similar echo pattern. However, scarring more typically occurs within the regions of suspensory ligament fibers. Therefore, the location of persistently echogenic tissue within the suspensory ligament can be helpful in making this distinction. The complex anatomy of the hind suspensory ligament is a limitation. In addition, there is a vessel, the deep metatarsal vein, that extends along the dorsal ligament margin in the proximal metatarsal region that should not be mistaken for decreased echogenicity in the ligament. Color flow will not always create an appreciable signal in the vessel because it is quite difficult to place the ultrasound beam at the proper angle. The best way to detect the vessels is to follow from proximal to distal with the probe in an off-angle position. Tracking and demonstrating that the anechoic region extends outside the ligament margins are helpful ways to differentiate a vessel from
suspensory ligament injury. In conclusion, complete ultrasound of the suspensory ligament requires a knowledge of the anatomy and normal anatomic variation between limbs, as well as an understanding of how pathologic change alters the normal anatomic characteristics. Assessment of the fat and muscle can provide valuable insight into pathologic change, especially in cases that do not have obvious alterations in the echogenicity of the fibers.

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