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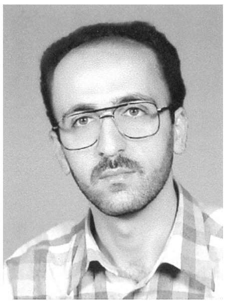

Principles of Ultrasonography of Tendons and Ligaments in the Horse

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Abstract

Equine lameness due to soft tissue disorders commonly occurs in the forelimbs, particularly involving the palmar metacarpal tendons and ligaments. Ultrasonographic diagnosis has proved highly popular as an easy, safe, non-invasive method of detecting these lesions, permitting not only their morphologic evaluation but, more importantly, their observation over time.
This paper presents a basic review of ultrasonography of tendons and ligaments of the equine limb especially of palmar/plantar metacarpus/metatarsus and pastern.

Introduction

Injuries to the tendons and ligaments especially of the palmar metacarpus are common and of great economic importance to the equine industry. Ultrasonography has been used in the diagnosis of tendon and ligament injuries for nearly 25 years. However, since then, with technological advances and decreasing equipment costs, this imaging modality is now more useful and readily available in practice. The key for the clinician is to produce images of the highest quality in order to maximize the diagnostic information obtained. Prior to the development of diagnostic ultrasonography, the diagnosis of tendon injuries was based primarily on palpation. Ultrasonography has enabled the practitioner to diagnose the presence of tendon and ligament injury, characterize the type of injury and quantitate its severity. Ultrasonography is currently being used to assess tendon healing and is becoming an essential part of the rehabilitation program for a horse recovering from a tendon or ligament injury.
Diagnostic ultrasonography has more recently been applied to the assessment of other less traditional musculoskeletal problems such as evaluation of bones, joints, muscle and nerves which are out of this article means.

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Key factors influencing the quality of an ultrasound image include equipment available, correct adjustment of the machine settings, patient factors (e.g. size, preparation, compliance, region of interest) and expertise of the operator.

Transducer Selection

A high frequency transducer is necessary to obtain optimal image quality of tendons and ligaments and a standoff is useful for the structures immediately beneath the skin surface. Without this standoff, a transducer artifact will appear superimposed on the structure immediately under the skin surface which is usually the superficial digital flexor tendon (SDFT). A 7.5-10.0 MHz transducer is ideal for obtaining quality images of the flexor tendons or ligaments in the horse and allows visualization of the structures up to 6 or 8 cm from the skin surface. As most of the SDFT is usually within 1 cm of the skin surface, this choice of transducer selection and the standoff provide optimal image quality to evaluate this structure. A 13.0 - 14.0 MHz transducer, if available, will result in superior resolution of the superficial structures.

Patient Preparation

Patient preparation is also important in obtaining a quality ultrasonographic image. The hair over the structures to be scanned should be surgically clipped with a #40 blade and the skin thoroughly cleaned. Shaving the hair over the affected structures may be also necessary, on occasion, to obtain optimal image quality. The skin should be free of all debris or "scurf" (dead sloughing skin cells) prior to beginning the sonographic examination. If there is a large amount of scurf on the limb, soaking the leg in warm water for 10-15 minutes or the application of a wet bandage will often soften the scurf adequately so that its removal is possible and obtaining a good quality ultrasound image is facilitated. The application of alcohol to the skin is also useful in obtaining a good image when clipping the hair on the limb is not an option. After cleaning the skin a liberal application of ultrasound transmission gel is necessary to provide an air free interface between the transducer and the skin surface. A better quality image is produced if a few minutes are allowed between application of gel and scanning.

Scanning Technique

The optimal images are obtained with the transducer held perpendicular to the structures being evaluated. This maximizes the amount of reflected ultrasound from the tendons and ligaments and prevents diagnosis of the false hypoechoic lesions.
The ultrasound examination should be performed with the horse weight bearing equally between both forelimbs and hindlimbs. The tendons and ligaments change in size, shape and echogenicity when not loaded by full weight bearing.
The tendons and ligaments should be scanned in two mutually perpendicular planes from their origin to insertion following the direction of hair growth. The limb is scanned transversely initially (the scan plane perpendicular to the structure's long axis). The tendon or ligament is displayed in its short axis cross-section (Fig 1). The sagittal image plane (the scan

plane parallel to the long axis of the structure) can then be performed to evaluate the pattern of fiber alignment (Fig 2).

Gain controls should be set at the optimal range. If the gain is set too high, the picture appears excessively hyperechoic, obliterate hypoechoic lesions. If the gain is set too low, the sonogram appears exaggeratedly hypoechoic, resembles the presence of an injury. The gain settings may have to be altered to suit the individual horse due to the different depths of penetration required. It is also important when scanning the tendons and ligaments of the palmar metacarpus that each structure is evaluated independently; therefore, optimal gain controls required for the SDFT may need to be altered to examine other tendons or ligaments.

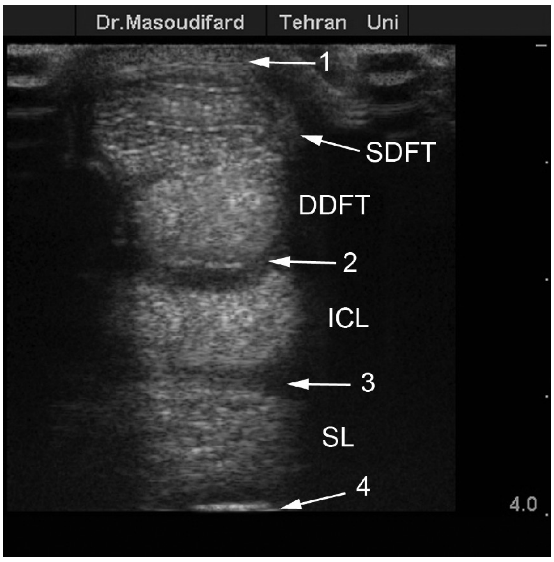

Figure 1: Normal transverse sonogram of the tendons and ligaments in the metacarpal region of a mature horse obtained 10 cm distal to the point of accessory carpal bone. 6-13 MHz linear-array transducer operating in resolution mode without standoff pad was used to obtain the image. 1. Thin echogenic skin and subcutaneous tissue, 2. Anechoic to hypoechoic carpal sheath, 3. Capillary and connective tissue layer, 4. Echogenic surface of the third metacarpus.

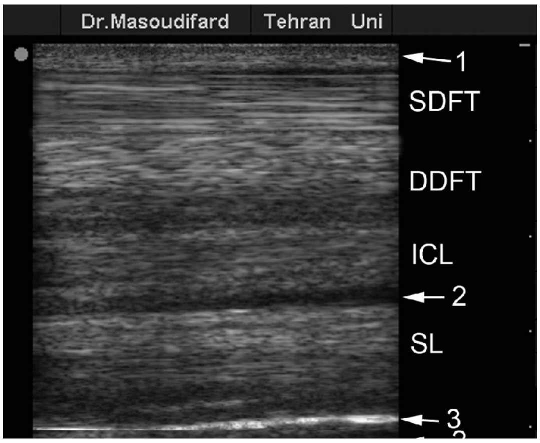

Figure 2: Normal sagittal sonogram of the tendons and ligaments in the metacarpal region of a mature horse obtained from 8 to 12 cm distal to the point of accessory carpal bone. 1. Thin echogenic skin and subcutaneous tissue, 2. Capillary and connective tissue layer, 3. Echogenic surface of the third metacarpus.

Scanning Zones

The tendons and ligaments can be measured in centimeters from a standard reference point such as the point of the accessory carpal bone, point of the tuber calcis or point of the ergot. This enables the veterinarian to compare tendons and ligaments in opposite limbs and to return on subsequent examinations to the same location within the injured tendon or ligament for follow-up assessments. The limb can also be divided into zones with each zone measuring approximately 4 cm in length. The forelimb is divided into seven zones beginning from just below the accessory carpal bone and ending at the fetlock joint. The zones are labeled 1A, 1B, 2A, 2B, 3A, 3B and 3C. Similarly, the hind limb can be divided into zones 1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B and 4C from the distal portion of the hock to the fetlock joint. There are also 4 zones for scanning the pastern that are shorter in length (approximately 2 cm): proximal first phalanx (P1) (P1A), mid P1 (P1B), distal P1 (P1C), and proximal second phalanx (P2) (P2A). A second zone can be obtained in some horses at the level of mid P2 (P2B).

Normal Ultasonogrphic Appearance of Tendons and Ligaments

Each tendon and ligament in the metacarpal, metatarsal and pastern region normally change in size and shape from its origin to its insertion. Therefore, a thorough knowledge of the anatomy of the structures under investigation and their interrelationships to one another is crucial for the accurate interpretation of the sonogram. The readers are referred to the anatomic text books.

Superficial Digital Flexor Tendon (SDFT):
The normal SDFT has a homogeneous and echogenic appearance and is slightly less echogenic than the deep digital flexor tendon. It is composed of long parallel fiber bundles that appear as long white echoes in the sagittal or long axis view and as a uniform distribution of pinpoint white echoes in the transverse or short axis view. The cross-sectional area (CSA) of the SDFT should be less than or equal to 1.2 cm^2 in the forelimbs in normal Thoroughbred and Standardbred horses. The tendon CSA at the identical level in each of the contralateral fore and hind limbs should be the same. The size and sonographic appearance of the SDFT changes in response to race training with the CSA of the tendon enlarging somewhat (approximately 10%) and the echogenicity of the tendon decreasing.

Deep Digital Flexor Tendon (DDFT):
The DDFT has a homogeneous and echogenic appearance, usually appears more echogenic than the SDFT, but may also be isoechoic with the SDFT. The DDFT has previously been described as being less echogenic than the inferior check ligament but a recent work indicated that the DDFT is actually the more echogenic tendinous or ligamentous structure in the metacarpal region. It also appears sonographically as long white echoes in the sagittal view and a homogeneous distribution of pinpoint white echoes in the transverse view.

Inferior Check Ligament (ICL)or Accessory Ligament of the DDFT (ALDDFT):
The ICL has a homogeneous echogenic appearance and may appear as the most echogenic structure in the proximal metacarpal region or as the next most echogenic structure after the DDFT. The echo pattern of the ICL is unchanged from that of the SDFT and DDFT.

Suspensory Ligament (SL):
The SL origin and body is more heterogeneous than the other tendinous and ligamentous structures because it is composed of muscle tissue, connective tissue and fat, in addition to ligamentous fibers. This accounts for significant variability in the normal sonographic appearance of the SL origin and body. The hind suspensory ligaments tend to have a greater percentage of muscle fibers than those in the forelimbs. Therefore, the hypoechoic areas seen in the normal SL should be consistent in size, shape and location between the right and left

limbs. The SL branches are similar in echogenicity with the flexor tendons and have a similar sonographic texture or echo pattern. The medial branch of the SL is usually 10% larger than the lateral branch in normal horses, but they have a similar shape.

Distal Sesamoidean Ligaments (DSL):

The distal sesamoidean ligaments also have a similar echo pattern to that of the flexor tendons and appear homogeneously echogenic. The straight distal sesamoidean ligament (SDSL) has somewhat of an hourglass shape, smallest in the mid pastern region. The SDSL can be imaged from its origin or near its origin on the base of the proximal sesamoid bones to its insertion on the proximal palmar or plantar aspect of the P2. The middle or oblique distal sesamoidean ligament (MDSL) can be scanned from its origin at the base of the medial and lateral sesamoid bones to its insertion on the palmar or plantar aspect of mid to distal P1. Immediately distal to the base of the proximal sesamoid bone is the origin of the MDSL, best located initially in its transverse section as a large oval to round structure.

Flexor Tendon Sheaths:

Digital sheath: The digital sheath is normally a thin echogenic structure that is difficult to separate from the tendons or annular ligament in the normal horse. The digital sheath is normally contains little or no visible fluid.

Carpal sheath: The carpal sheath is imaged as a thin circular echogenic structure encircling the SDFT and DDFT, with fluid usually visible in the carpal sheath between the DDFT and ICL in the proximal to mid metacarpal region along the medial aspect of the limb. The wall of the carpal sheath is normally a thin echogenic structure that is difficult to separate from the tendons, except where fluid is contained within the sheath.

Tarsal sheath: The tarsal sheath can be imaged surrounding the DDFT along the medial aspect of the hock and in the proximal metatarsal region. The tarsal sheath is also a thin echogenic structure that is difficult to distinguish from the DDFT unless there is fluid contained within the sheath.

Palmar/Plantar Digital Annular Ligaments:

The annular ligament of the metacarpophalangeal / metatarsophalangeal joint cannot usually be distinguished as a separate structure sonographically. The proximal digital annular ligament is a continuation of the digital annular ligament in the distal metacarpal/metatarsal region and is closely adhered to the palmar/plantar aspect of the SDFT in the proximal pastern. The distal annular ligament forms a sling over the distal part of the DDFT. These two structures are very thin in normal horses and are difficult to distinguish from the adjacent digital sheath.

Clinical Signs of Tendon and Ligament Injury

Diagnosis of tendinitis or desmitis should be suspected when the characteristic signs of swelling, heat and sensitivity in the tendon or ligament are detected. In many horses, the heat and sensitivity are transient, lasting only several days. Persistent swelling of the flexor tendons or ligaments should prompt sonographic examination of the palmar metacarpal region to determine if a tendinitis or desmitis is present. Lameness may be present but its absence does not rule out the existence of tendinitis or desmitis. Lameness is most likely to be present in horses with deep digital flexor tendinitis or suspensory ligament desmitis.

Sonographic Findings in Tendon and Ligament Injury

Echogenicity, size, shape and fiber pattern or fiber alignment of the tendons and ligaments are the basis for assessment of tendon or ligament injury. Evaluating tendon and ligament echogenicity is usually somewhat subjective, and is dependent on both the equipment settings and the scanning technique of the operator. CSA measurement is the most valid and accurate measurement technique for detection of the tendon or ligament injury. However, width and thickness measurements should be made if tendon or ligament CSA cannot be determined. Thus, knowledge of the normal dimensions and echogenicity of the structures is necessary in order to identify abnormalities. The normal measurements and ultrasonographic appearance of tendons and ligaments have been reported in different horse breeds, although, the opposite normal limb may be used as the most reliable reference of the echogenicity and measurements of the same horse.
Mild enlargement of the tendon or ligament with a diffuse decrease in tendon or ligament echogenicity and preservation of fiber alignment is frequently detected in horses with newly discovered tendinitis or desmitis. This is an early indication of tendon or ligament inflammation or injury and often precedes the development of a bowed tendon or torn ligament. The most common discrete injury to the tendon or ligament is a central core lesion.

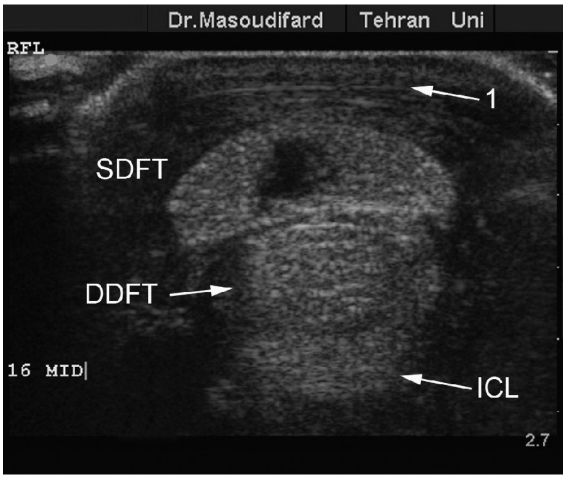

Figure 3: Transverse sonogram of the SDFT and DDFT in the metacarpal region obtained 16 cm distal to the point of accessory carpal bone (at the MIZ) revealed a well defined anechoic region (core lesion) within the SDFT. CSA measurements confirmed the tendon CSA as 115 mm^2 and lesion CSA as 24 mm^2 which involves about 21% of the tendon. The echogenicity grade of the lesion is (3). 1. Thickened skin and subcutaneous layer.

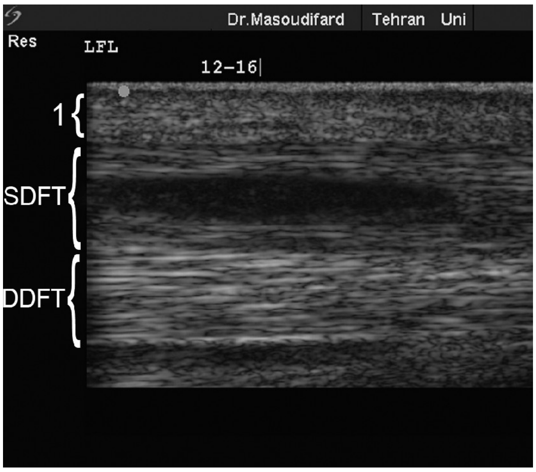

Figure 4: Sagittal sonogram of the SDFT and DDFT in the metacarpal region obtained from 12-16 cm distal to the point of accessory carpal bone revealed loss of fiber pattern and decreased echogenicity in the central region of SDFT. The fiber alignment grade of the lesion is (3). 1. Thickened skin and subcutaneous layer.

A central core lesion appears sonographically as a discrete anechoic or hypoechoic area within the center of the tendon or ligament (Fig 3). Core injuries to the tendon or ligament can also occur in any portion of the tendon or ligament, i.e. medial, lateral, dorsal or palmar. Fiber damage to the tendon or ligament appears sonographically as an anechoic or hypoechoic region lacking a parallel fiber pattern (Fig 4). It is of vital importance for the final assessment of tendon integrity to combine transverse information with longitudinal scans.

***SDFT**:* The most common injuries occur to the SDFT which lies immediately under the skin surface. This tendon is also the most frequently injured tendon or ligamentous structure at the level of the pastern. The SDFT may be damaged at any site from its muscular attachment to its insertion onto the first and second phalanges. The most common site for SDFT injuries is in the mid-metacarpal region when a swelling of the tendon is usually evident, resulting in a 'bowed' appearance of the palmar metacarpus when viewed from the lateral aspect. Ultrasonographic examination of these injuries often reveals a focal area of decreased echogenicity (core lesion) within the central, medial, lateral, dorsal and/or palmar areas of the tendon (Figs 3 and 4).

***DDFT**:* Injury to the DDFT in the mid-metacarpal area is extremely rare. Tendonitis of the DDFT most commonly occurs at the level of the metacarpophalangeal joint or more distally. Clinically, this usually presents with a painful digital sheath effusion. Ultrasonographic examination of these cases often reveals a focal area of decreased echogenicity within the DDFT at the level of the metacarpophalangeal joint

***ICL**:* The ICL is the third most frequently injured tendinous or ligamentous structure in the forelimb but is rarely ever injured in the hindlimb. Desmitis of the ICL is a common injury typically found in older (over 10 years of age) horses or ponies. Enlargement of the ICL results in a reduction in the soft tissue gap between the SL and the ICL.

***SL**:* The second most frequently injured structure is the SL. Desmitis of either or both SL branches is probably the most common injury to the suspensory apparatus. Early detection of suspensory branch injuries is important to avoid severe suspensory breakdown. Caution is required when diagnosing mild SL desmitis because the body and proximal of the SL represent ultrasonographically small anechoic and hypoechoic areas. In such cases, it is advisable to examine the contralateral limb to confirm the significance of these findings.

***DSL**:* Desmitis of the MDSL appears more common than desmitis of SDSL. Ultrasonographic examination of these structures is difficult due to the formation of artifacts, particularly when examining the SDSL.

***Tendon Sheaths**:* With distention of the digital sheath, anechoic fluid can be imaged between the flexor tendons and around the dorsal, palmar or plantar, and medial and lateral aspects of the flexor tendons. Idiopathic tenosynovitis of the digital sheath is usually associated with low grade lameness. Ultrasonographic examination demonstrates the presence of anechoic synovial fluid within the sheath and a variable amount of synovial membrane hypertrophy and thickening. In septic tenosynovitis, the synovial fluid often appears more echogenic than normal due to its cellular nature, and marked synovial thickening may also be present. Distended carpal sheath will bulge primarily along the proximal, middle and medial two thirds of the metacarpus. The carpal sheath may also distend along the distolateral aspect of the carpus, cranial to the ulnaris lateralis.

Sonographic Assessment of Injury Severity

The severity of tendon injury should be characterized ultrasonographically. Assessments of tendon or ligament CSA at its largest point in each zone, the lesion CSA in each injury zone, the echogenicity or type of the lesion, the fiber alignment of the lesion, and the length of the lesion are all indications of the severity of the tendon or ligament injury. Echogenicity and fiber alignment of the lesion within the tendon or ligament is graded in each zone using a scale from 0-3 as following:
Echogenicity grading: (0) normal to near normal echogenicity, (1) mostly echogenic, (2) 50% anechoic and 50% echogenic, (3) mostly anechoic.
Fiber alignment grading: (0) 75-100% parallel fiber alignment, (1) 50-75% parallel fiber alignment, (2) 25-50% parallel fiber alignment, (3) 0-25% parallel fiber alignment.
The length of the lesion is measured in cm distal to the point of the reference. The location of the lesion should be described (central, medial, lateral, dorsal, palmar or plantar) and the lesion should be described as discrete or diffuse. The amount of peritendinous soft tissue swelling should also be assessed.
Sonographic examination of the entire tendon or ligament and measurement of the tendon or ligament cross-sectional area (TCSA) and lesion cross-sectional area (LCSA) in each zone is critical in assessing tendon or ligament injury severity. Lesion and tendon or ligament CSA should be measured at each of the zones in the metacarpal /metatarsal region. If the tendon injury extends into the pastern, the tendon and lesion CSA should be measured in each of the zones in the proximal to mid pastern. CSA measurements should be summed to calculate injury severity for the entire tendon or ligament.

Tendon or ligament Injury Severity = ∑ LCSA in zones 1A + 1B + 2A + 2B + 3A + 3B + 3C / ∑TCSA in zones 1A + 1B + 2A + 2B + 3A + 3B + 3C

Tendon Injury Severity (Metatarsus) = ∑LCSA in zones 1A + 1B + 2A + 2B + 3A + 3B + 4A + 4B + 4C / ∑TCSA in zones 1A + 1B + 2A + 2B + 3A + 3B + 4A + 4B + 4C

Injuries to the total tendons or ligaments are classified as:
Mild: The injury involves less than or equal to 15% of the total tendon CSA or involves up to 50% of the tendon at the maximum injury zone (MIZ).
Moderate: The tendon damage is greater than 15% but less than or equal to 25% of the total tendon CSA or involves 50-75% of the tendon at the MIZ.
Severe: The injury involves greater than 25% of the total tendon CSA or involves greater than 75% of the tendon at the MIZ.
The total tendon or ligament echogenicity and fiber alignment score should also be calculated by summing all the scores in each of the zones and dividing by the number of zones. These initial sonographic findings will be used to characterize the tendon or ligament injury and quantify its severity.

Scanning Time

The most informative time to scan a tendon is believed to be seven to 14 days post injury. By this stage, most of the peritendinous swelling will have resolved, the risk of skin irritation following shaving or clipping will be reduced and the lesion will often appear ultrasonographically at its most severe. This initial scan will enable an overall assessment as to the nature and severity of the injury, allowing the examiner to determine the duration of rest required.

Sonographic Monitoring of Tendon or Ligament Healing

The anechoic lesion imaged in the acutely injured horse corresponds to an area of hemorrhage at the site of fiber rupture. Clot in the acutely injured tendon or ligament may appear echoic and may be mistaken by the sonologist for normal tendon or ligament. This mistake can be avoided by evaluating the sagittal view of the tendon or ligament in the acutely injured horse. In spite of the normal or near normal echogenicity of organized hemorrhage, it lacks a linear fiber pattern. The appearance of an anechoic lesion associated with cavitation or lysis of the clot may take 5-7 days or more in some horses.

With progressive tendon or ligament healing, the CSA of the lesion and the tendon or ligament should decrease. The lesion site gradually fills with hypoechoic amorphous echoes that should represent granulation tissue and immature fibrous tissue. The echogenicity of the injured area gradually increases and the demarcation between the injured and uninjured tendon or ligament becomes less distinct. Short randomly aligned linear echoes can be imaged in the repairing region in the sagittal scan plane. Ideally, when the tendon has healed, its echogenicity should be identical to the surrounding non-injured areas and linear echoes of the fibers should elongate into their more normal length.

Sonographic Follow-Up

Follow-up sonographic examinations should be performed on horses with tendon or ligament injuries every 2-3 months and at pivotal changes in the horse's exercise program. Increases in exercise intensity should not occur unless continued sonographic improvement is detected. Increases in tendon or ligament CSA of greater than 10% for the entire tendon or ligament or greater than 20% at any one injury zone are likely indications of excessive loading for the healing that has occurred and re-injury is likely if the current exercise program is maintained. These horses should have their exercise program reduced until improvement in the sonographic appearance of the tendon or ligament occurs. If follow-up examination shows at least 70% decrease in the lesion CSA of tendon in the MIZ, then it can be allowed for the horse to enter race training.

Several investigators have demonstrated the importance of imaging a good fiber pattern throughout the entire tendon or ligament prior to beginning cantering or galloping. In all these studies, a better quality of fiber repair was significantly associated with improved chances of horses returning successfully to the races or other types of rigorous athletic competition and competing without re-injury for at least 5 starts.

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