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ADVANCED ORTHOPAEDICS

ULTRASONOGRAPHIC IMAGING THE FLEXOR TENDONS IN A CLINICAL CONTEXT

Roger K.W. Smith, Professor, MA VetMB PhD DEO DipECVS MRCVS
RCVS and European Specialist in Equine Surgery
Professor of Equine Orthopaedics

Indications for ultrasonographic evaluation of the digital flexor tendons
1) Diagnosis - while most digital flexor tendon injuries are easily detectable by palpation, palpation provides a poor objective assessment of the severity. A base-line scan, often performed 7-10 days after injury because injuries can worsen initially, can provide an assessment of severity that may relate to prognosis.
2) Management – follow-up ultrasonographic examinations (ideally every 2-3 monthly) are used to optimise management decisions during the rehabilitation phase.

Review of ultrasonographic technique (see also ‘Ultrasound in the diagnosis of lameness’)
The limb should ideally be prepared by clipping and washing (with surgical scrub followed by surgical spirit) to facilitate the best quality images. The horse should be standing square and both transverse and longitudinal images obtained in a methodical fashion from the palmar aspect throughout the metacarpal and/or pastern regions. BOTH limbs should be examined as many cases of strain-induced tendon injury have bilateral components.

There is no standardised technique but a system of seven levels or zones is recommended, each of which has characteristic anatomical features. The palmar/plantar pastern region is also divided into 3-5 levels or zones. The distal two zones correspond to the more distal position that can sometimes be achieved with a small footprint transducer, although a more distal examination can be achieved with caudal limb position which hyperextends the DIP joint. At least one longitudinal level is usually achievable with a linear transducer depending on the relative size of transducer and pastern. Easier access can be achieved by raising the foot on a block. Because a number of structures pass obliquely across the first phalanx oblique 45° views should be used to perform a complete examination.

Ultrasonographic appearance of the digital flexor tendons

Superficial digital flexor tendon (SDFT)
Proximally, the tendon lies within the carpal sheath as a semi-circular structure, palmaromedial to the deep digital flexor tendon (DDFT). As the tendon runs distally it reduces in cross-sectional area (CSA) and adopts a rounded medial contour and sharper lateral border. In the distal metacarpal region it thins in a dorsopalmar direction and extends a ring of tissue around the DDFT (the manica flexoria).

Distal to the fetlock the SDFT continues as a thin structure which then divides into two branches in the mid-pastern region. Prior to its division, the distal ‘manica’, another ring of the SDFT surrounding the DDFT, is usually visible deep to the DDFT. It is a useful landmark, but contrary to its more proximal sister, is rarely significantly injured. The two SDFT branches run abaxially to insert, via the thick fibrocartilaginous middle scutum, onto the proximopalmar aspect of the middle phalanx. These branches are best observed ultrasonographically as comma-shaped structures with the transducer on the palmarolateral and palmaromedial aspects.

Deep digital flexor tendon (DDFT)
In the proximal forelimb the DDFT lies dorsolateral to the SDFT. As the tendon runs distally, it becomes more circular and also reduces in CSA. In the mid-metacarpal level, the accessory ligament of the DDFT (ALDDFT) joins the DDFT on its dorsal surface and becomes enclosed in...
the one paratenon. However, the fibres of the ALDDFT can be identified, separated from the DDFT by a hypoechoic curved line, for an appreciable distance distally. In the distal metacarpal region, the DDFT increases in CSA and becomes oval in shape at the level of the metacarpophalangeal joint. In the distal metacarpal region within the proximal pouch of the digital sheath, abaxial synovial plicae connect the DDFT to the digital sheath wall both medially and laterally. Although not normally visible in the non-distended sheath, they are easily identified with the improved contrast associated with sheath distension. The plicae should not be confused with adhesions, but they are useful structures with which to assess the status of the synovial membrane.

In the hindlimb, the dorsal surface of the DDFT usually has a well circumscribed hypoechoic region within it in the proximal limit of the digital sheath which is normal.

Within the pastern region, the DDFT will frequently contain a dorsal hypoechoic region immediately distal to the ergot due to off-incidence artefact from the change direction in the DDFT. As the DDFT runs distally it adopts a bilobed appearance with the distal palmar/plantar pouch of the digital sheath superficial to the DDFT. A normal thin mesotenon is sometimes visible distally between the DDFT and the digital sheath.

The DDFT can be examined further distally but requires a small foot-print (eg curvilinear) probe which can be placed in the longitudinal plane between the bulbs of the heel. This allows identification of the DDFT distally to the level of the proximal border of the navicular bone (although off-incidence). The DDFT overlying the navicular bone and inserting onto the solar surface of the distal phalanx can be seen when scanning through the frog although only the central portions of the tendon are visible.

**Ultrasonographic pathology**

**Superficial digital flexor tendinopathy**

A common manifestation of acute injury to this tendon is a concentric hypoechoic/anechoic lesion visible in the centre of the tendon (hence the usual term, ‘core lesion’), usually centred in the mid-metacarpal region, and accompanied by enlargement and subcutaneous oedema in the acute stage. Lesions can also be localised eccentrically to the borders of the tendon – medially, laterally, dorsally or palmarly. Often dorsal lesions are thought to be associated with more lameness presumed to be because of the direct pressure exerted by the DDFT onto the lesion under weight-bearing load.

In very subtle cases, often the only finding can be enlargement and/or change in shape of the tendon. This can be accompanied by peritendinous oedema, which is not specific for tendonitis and can also result from local trauma. Providing there is no evidence of tendon injury and the oedema disappears, work can be recommenced after only a short period of rest. However, persistent oedema suggests the presence of tendonitis.

Not all lesions involved local abnormalities and another common manifestation is a generalised hypoechogenic tendon. This may represent either a tendon that is healing in which the core lesion has disappeared, or, if the injury is recent, more diffuse damage to the tendon and/or intratendinous oedema.

Injury can also occur to the SDFT in the fetlock (‘low bow’) and pastern regions where it is associated with variable amounts of digital sheath effusion. Damage to the SDFT in the region of the fetlock canal appears ultrasonographically as a hypoechoic tendon with minimal enlargement because of the constraints of the palmar annular ligament. As a result, these injuries are often associated with secondary thickening of the palmar annular ligament. Injury to the branches of the SDFT is best identified by enlargement and hypoechogenicity of individual branches best observed with the transducer positioned palmarolaterally or palmaromedially. There is usually secondary subcutaneous fibrosis with these injuries in contrast to those affecting the SDFT more proximally. If the injury is localised to the region of the metacarpophalangeal joint or distally, then there may be evidence of previous injury to the mid-metacarpal region.

Complete rupture of the SDFT is the most severe extreme of an over-strain injury and often results in an almost totally anechoic region of the SDFT surrounded by a thin echogenic line (the paratenon, which usually remains intact unless the injury has been caused by percutaneous trauma). Evidence of damage will also be apparent proximal and distal to the rupture. If the
tendon ends have retracted, the outline of the paratenon at the site of the rupture may not be particularly enlarged but bunched-up retracted fibres will be identifiable proximal and distal to the rupture site. The SDFT also becomes medially displaced because of lengthening of the tendon.

**Semi-objective assessment of injury to the SDFT**

Objective measurements potentially allow a better determination of prognosis and assessment of healing. The following measurements have been suggested:

1. **Cross-sectional area (transverse image)** - there is a large inter-individual variation in CSA in normal horses - 80-130mm² for Thoroughbreds. A >20% difference between limbs is considered a significant enlargement, although this may not be the case if both limbs are affected.

2. **The percentage of damaged tendon (transverse image)** for focal lesions. The CSAs for both the size of the focal lesion and the total tendon CSA at each individual level can be summed for all seven levels or zones to give an approximation to the 'volume' of the lesion over the volume of the tendon. This has been used to give, what is thought to be, the optimal assessment of severity – 0-15% of the tendon affected are mild injuries, 16-25% moderate injuries and >25% severe injuries. An alternative method is to consider the maximum injury zone only where a mild injury involves <10% of the cross-sectional area; a moderate 10-40% and a severe injury >40%, although this obviously does not take into account the length of the lesion.

3. **The type of lesion (i.e. degree of echogenicity)**
   - Type 1 - Lesion is hypoechoic; more white than black
   - Type 2 - Lesion is hypoechoic; same amounts of white and black.
   - Type 3 - Lesion is hypoechoic; more black than white.
   - Type 4 - Lesion is anechoic; totally black.

4. **Fibre alignment score (longitudinal image)** – 0 (76%-100% parallel fibres; normal) to 3 (0-25% of parallel fibres) – assessed subjectively.

**Assessment of healing**

All tendon injuries should ideally be monitored ultrasonographically at up to 3 monthly intervals or before and after a change in the exercise level. At each examination, the following indicates good progress:

1. A stable or decreasing cross-sectional area - sequential CSA measurements provide the most sensitive indicator of exercise:tendon healing mismatch during the rehabilitation phase. If the CSA at any level increases by more than 10%, it is advisable to maintain or lower the exercise level.

2. An increase in the lesion echogenicity and a homogeneous texture

3. An improvement in the striated pattern seen longitudinally (fibre alignment)

4. Absence of peritendinous fibrosis and adhesions.

More recently, the blood flow within healing digital flexor tendons can be assessed with the limb raised using Doppler. Normal digital flexor tendons usually have minimal discernible blood flow while, after injury, a pronounced vascular pattern is usually visible. Hypervascularity is normal in the healing process but should subside as healing progresses (normally between 3-6 months after injury) and its re-appearance can be an indication of re-injury.

Horses suffering from tendonitis are constantly at risk of re-injury. Healing, determined histologically, takes at least 15-18 months. The mean interval between injury and return to training in racehorses is dependent on the severity of the initial injury and varies between 9 and 18 months. Sports horses may be able to return to full work in a shorter time but even the mildest ultrasonographically detectable injuries should have at least 6 months off. Occasionally horses are returned to full work prior to full resolution of the ultrasonographic lesion, however, this success may be due to the horse being capable of sustaining work in spite of the presence of a tendon injury.

**Chronic tendinopathy**

The ultrasound characteristics of chronic tendinopathy are more variable and can be subtle. The tendon is often enlarged but its echogenicity varies from hypoechogenic through normoechogenic to hyperechogenic if the injury was severe and substantial fibrosis has occurred.
The intratendinous pattern is usually more coarse, with a lack of striations in the longitudinal images. In some cases, the outline of the original core lesion can still be seen. Mineralisation may occur which causes acoustic shadowing although if the calcification is florid, previous intratendinous injection of depot corticosteroids should be suspected. Off-incidence transducer orientation can help to define areas of disorganised scar tissue in chronic injury because it retains its echogenicity at greater transducer angles than normal tendon.

**Local trauma**

Over-strain injuries (described above) need to be distinguished from local trauma caused by a bandage (so-called ‘bandage bow’) or percutaneous trauma from, for example, a hindfoot. The effects of local trauma can vary from localised peritendinous oedema with no evidence of intratendinous damage, through localised hypoechoic/anechoic lesions on the palmar surface of the tendon, to partial or complete transection. Local traumatic injuries do not extend far proximodistally. However, partial lacerations can be associated with longitudinal splits in the tendon extending proximally or distally resulting from altered shear stresses. Partial lacerations can also be easily missed if the examination is restricted to the site of the wound as they often occur when the tendon is fully loaded so that the site of injury moves more proximally in the resting or reducing weight-bearing limb. Ultrasound is therefore very useful to identify these sites of injuries not visible through the wound. Complete transection of one branch of the SDFT in the pastern region results in a shift in position of the SDFT towards the side of the intact branch more proximally.

Sepsis following a penetrating injury (or occasionally, haematogenous spread) of the SDFT is rare and usually gives an anechoic lesion, often with a communicating tract to the periphery of the tendon. Aspiration of the lesion will yield a sample containing large numbers of degenerate neutrophils. These lesions do not usually cause gross enlargement of the affected tendon and change rapidly in time in comparison to the core lesion in a tendon strain. If the lesion is present within a tendon sheath, there will usually be an accompanying septic tenosynovitis.

**Manica flexoria tears**

This is a common cause of digital sheath tenosynovitis, especially in hindlimbs. Ultrasonographic diagnosis is difficult but an altered position of the manica flexoria seen in a longitudinal scan in the midline immediately proximal to the metacarpo-/metatarso-phalangeal joint is probably the best indicator of a torn manica flexoria. Tenoscopic assessment provides the optimal evaluation.

**Deep digital flexor tendinopathy**

Deep digital flexor tendon injuries are extremely rare in the metacarpal region but they do occur within the confines of the digital sheath. Of the strain-induced deep digital flexor tendon injuries there appears to be two forms – the intratendinous injury and surface tears.

**Intratendinous injury**

Intratendinous injuries are frequently centred at the level of the metacarpophalangeal joint and result from a sudden over-extension of the distal interphalangeal joint when the metacarpophalangeal joint is fully extended when the limb is weight-bearing. These injuries are frequently associated with considerable disruption of the tendon and marked and persistent lameness. There is usually concurrent tenosynovitis and, as with most soft tissue injuries in the phalangeal region, subcutaneous fibrosis. Other lesions are manifest by focal hypoechoic lesions proximal or distal to the metacarpophalangeal joint. Because of the location of the injuries within the digital sheath, healing is, at best, problematical. In the chronic stage, the lesions often persist as hypoechoic lesions with or without areas of calcification. Lameness usually persists, arising either from tenalgia and/or from adhesion formation within the sheath. Such adhesions can distort the tendon shape.
Border tears
Damage to the surface of the deep digital flexor tendon can occur as a variant of over-extension injury to the tendon. These frequently occur at the lateral and less commonly, medial borders of the deep digital flexor tendon in the region of the metacarpophalangeal joint, most commonly in the forelimbs, presumably due to excessive forces during over-extension which compress the tendon and cause a pressure induced rupture. Due to their intra-synovial location and being bathed in synovial fluid, healing does not occur and these lesions often persist, being responsible for persistent digital sheath tenosynovitis and lameness.

Confident diagnosis of these tears using ultrasonography is difficult - greater sensitivity in their detection can be made by using an oblique transducer position to assess the lateral and medial borders. In contrast, many central defects may extend to the surface of the tendon without penetrating the epitenon and so may not be visible tenoscopically. Hence a negative finding on ultrasound does not rule out the presence of a tear and tenoscopy is recommended to identify occult tears and should certainly be considered in those cases of tenosynovitis that have failed to respond or recurred after intrathecal medication.

Local trauma
Local trauma to the palmar/plantar aspect of the pastern is common during over-extension of the metacarpo-/metatarso-phalangeal joint at maximal exercise. Due to the close proximity to the skin, such injuries frequently damage the digital sheath and DDFT. Such combination injuries can result in digital sheath (and rarely DDFT) sepsis if open, giving rise to effusion and synovial thickening evident ultrasonographically. This synovial thickening usually also involves the epitenon surrounding the DDFT giving rise to a ‘halo’ appearance to the tendon. Such signs, while not pathognomonic for sepsis, are strongly suggestive of it and should indicate synoviocentesis to confirm or refute the presence of sepsis. Local trauma will cause variably sized hypoechoic lesions within the DDFT and enlargement, and are often associated with adhesion formation between the damaged areas of the DDFT and sheath wall. Individual adhesions can sometimes be visualised ultrasonographically when surrounded by fluid (cf normal mesotenon/synovial plicae). Poor tendon border definition has been suggested as a sign of adhesions but can lead to over-estimation of adhesions. When percutaneous trauma does not penetrate the skin, damage can still be induced in the underlying DDFT (blunt contusion) which may only become visible as a hypoechoic lesion over time. Therefore, if clinical signs persist, a repeat ultrasonographic examination is indicated after 2-4 weeks.