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ULTRASONOGRAPHY IN THE DIAGNOSIS OF LAMENESS

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Introduction
Diagnostic ultrasound is now an accepted and routine procedure for evaluation of soft tissue injuries in the horse. The increased frequency of the use of this technique and the rapidly improving technology now enables even small portable ultrasound machines to provide good quality, diagnostic images. This presentation will address the techniques and basic interpretative skills needed to produce diagnostic quality ultrasound images.

Indications for an ultrasonographic examination
(a) Investigation of soft tissue injury.
(b) Investigation of the surface of bone.
(c) Investigation of joint abnormalities.
(d) Investigation of wounds.
(e) Investigation of an area causing lameness, as determined by diagnostic anaesthesia, with negative clinical and radiographic findings, or radiographic findings that suggest a soft tissue injury.
(f) Evaluation of structures likely to be concurrently or previously injured.
(g) Comparative contralateral limb

Ultrasoundographic equipment:
In most practice situations, a portable ultrasound machine is essential. There are a multitude of such machines available on the market, but below (see table 1) are a list of some features to consider when trying out an ultrasound scanner.

Ultrasoundographic technique for the metacarpal and pastern regions
Careful preparation of the area is essential if good diagnostic images are to be obtained. The skin should ideally be clipped with fine-bladed clippers, taking care to avoid causing damage to the skin as this can cause swelling after scanning. For evaluation of the flexor tendons and proximal suspensory ligament, a narrow strip of skin from the very palmar aspect of the limb is all that needs to be clipped. For the accessory ligament of the deep digital flexor tendon and the suspensory ligament branches, the hair also needs to be clipped from the medial and lateral aspects of the limbs directly overlying these structures. In some cases, owners/trainers request for the limbs to be scanned without clipping. In such circumstances, it has to be emphasised that subtle pathology may be missed and it is usually not possible to obtain a diagnostic quality scan without clipping in those horses with large amounts of feather.

The area should be prepared in a two stage process. First, a surgical scrub is used to clean off the debris after clipping, followed by cleaning with surgical spirit which degreases the skin and removes the bubbles created by the surgical scrub. Any excess is wiped from the limb and then high viscosity contact gel rubbed well into the skin. The area is then ready for scanning.

The horse should be standing square so that both limbs are evenly loaded. Sedation may be necessary, although the lower doses of α-2 agonists (detomidine or romifidine) should be used to avoid swaying movements after sedation. Any procedure for examining the metacarpal region ultrasonographically should be performed methodically.

There is no standardised technique but a system of seven levels or zones is recommended, each of which has characteristic anatomical features (see figures 1 and 2). Recognising these levels allows complete evaluation of the palmar soft tissue structures and, by familiarity with the anatomy, helps in the identification of abnormalities. In horses of similar size (e.g. racehorses),...
the distance the transducer lies below the accessory carpal bone is an alternative method. Either a ruler can be held adjacent to the limb to measure the distance, or a tape with centimetre divisions marked on it, can be stuck to the lateral aspect of the limb before scanning. Even with this system, images are usually taken from seven different points down the limb, separated by 3-4 cm, similar to the level system described above.

Having obtained transverse images, it is imperative that they are combined with longitudinal images. With longer transducers, it is not necessary to obtain seven separate levels; usually three or four will suffice.

The suspensory ligament branches need to evaluated from the medial and lateral aspects of the limb because of edge refraction shadowing artefacts cast by the borders of the flexor tendons run through the branches. Both transverse and longitudinal images are obtained with the transducer positioned directly over the branches.

Finally, it is a good idea to always evaluate both limbs as many strain injuries of the tendon and ligaments of the distal limb are bilateral with one limb more severely affected than the other. In addition, the contralateral limb can be used for comparison.

For the pastern region, the skin should be clipped to include the medial and lateral aspects because many of the soft tissue structures in the pastern run obliquely and have to be assessed by moving the transducer from the midline to more oblique positions. The palmar/plantar pastern region is also divided into a number of zones (P1a-c; P2a-b). The distal two zones correspond to the more distal position that can be frequently achieved with a sector probe, although a fourth level can be obtained with a linear probe if the limb is placed caudally so as to hyperextend the DIP joint. A single longitudinal level is usually achievable with a linear transducer. If it proves difficult to position the probe correctly in the pastern region because of the proximity of the floor, the foot can be raised by placing it on a block.

Adjunctive techniques

(1) Off-incidence artefact.

The normal correct orientation of the transducer is 90° to the orientation of the tendon fibres as this will produce the brightest image with the least artefacts. However, tilting the transducer by more than 5-7 degrees from this optimal position highlights the borders of the tendon while the central portion goes dark. This can be helpful in defining borders that are difficult to identify. Furthermore, such off-incidence artefact can help to define areas of disorganised scar tissue in chronic injury because it retains its echogenicity at greater transducer angles than normal tendon.

(2) Doppler imaging of tendon

The blood flow within healing digital flexor tendons can be assessed using Doppler imaging but only when the limb is raised. Normal digital flexor tendons usually have minimal discernible blood flow while, after injury, a pronounced vascular pattern is usually visible, which, in the case of superficial digital flexor tendinitis, usually originates from its deep surface. Hypervascularity is normal in the healing process but should subside as healing progresses.

Basic interpretation

It is important that all categories are assessed rather than concentrating on one particular aspect of ultrasonographic change (e.g. echogenicity) and that the injured structure is imaged in both transverse and longitudinal images at all times to help determine the significance of the lesions. In addition, almost all tendon or ligament injuries are associated with a degree of oedema in the acute stages. It is helpful to compare findings with the contralateral limb, although it must be remembered that many tendon and ligament injuries of the distal limb are bilateral. Ultrasonographic change can be divided into six different categories:

(1) Echogenicity

For tendon injuries, in general, hypoechoic change within the tendon suggests an acute injury, while hyperechoic change is chronic. However, there is considerable overlap and tendons with superimposed acute injury on chronic change can have both present. Echogenicity has been graded as 0 for normal echogenicity; 1 for mildly hypoechoic (more white than black); 2 for moderate hypoechoicity (equal amounts of white and black); and 3 for severe hypoechoicity (more black than white).
(2) **Size**
An increased in cross-sectional area is one of the most sensitive indicators of damage to a tendon or ligament although there is a large variation within a population. The contralateral limb can be used as a comparator although it must be remembered that many tendon and ligament injuries have bilateral components. CSA should also be used to monitor repair and optimize exercise level - for superficial digital flexor tendon injuries, an increase in cross-sectional area over 10% from that measured previously suggests that the exercise level is too high.

(3) **Pattern**
The characteristic striated (or 'fibrillar') pattern of tendons in the longitudinal image are a good indicator of the quality of the tendon repair. A grading system (fibre alignment score, or FAS) has been used to provide more objectivity. 0 is a normal striated pattern (76-100% parallel fibres); 1 a slight reduction (51-75% parallel fibres); 2 a moderate reduction (26-50% parallel fibres); and 3 a severe reduction in the striated pattern (0-25% parallel fibres). The better the FAS when the horses starts back in full work, the better the prognosis.

(4) **Shape**
Alterations in the shape of the tendon is sometimes one of the earliest signs of tendon injury. Adhesions within a tendon sheath can cause altered shape and position of the affected structure.

(5) **Position**
Severe damage results in an elongated tendon which, in the case of the superficial digital flexor tendon, becomes displaced medially. Lacerations of one SDFT branch in the pastern region will cause displacement of the SDFT proximal to the fetlock to the other side of the limb.

(6) **Margination**
Marginal defects can occurred in a variety of soft tissue structures due to local trauma or due to tears within synovial cavities. They cause alterations in the margin of the structure and can be visible ultrasonographically to a variable degree – thus a negative scan does not preclude the presence of a tear. Acute tendon injuries are usually associated with surrounding oedema, while surrounding fibrosis is more common in pastern injuries and for ligament rather than tendon injuries.

**Take home message – Five important rules of musculoskeletal ultrasound**
- Always prepare the limb well
- Always scan both limbs
- Always scan the whole area
- Always use transverse and longitudinal images (and other images if appropriate)
- Always look at the radiographs first if evaluating injury with bony abnormalities
### Table 1 – Some features of an ultrasound machine relevant to musculoskeletal ultrasonography.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transducer</td>
<td>A linear transducer is the transducer of choice for most musculoskeletal ultrasonography as it gives the best transverse and longitudinal images of tendons. The size or design of the transducer is not particularly important for scanning of the metacarpal region, although large transducers can be difficult to use in other less accessible areas (such as the pastern). A rectal probe can be used very satisfactorily for tendon scanning and therefore probably gives the greatest flexibility in practice.</td>
</tr>
<tr>
<td>Frequency</td>
<td>The highest frequency that will allow the full depth of tissue to be imaged will give the best definition. For most musculoskeletal indications, 7.5MHz will suffice. Broad bandwidth technology is ideal and allows the selection of different frequencies with the same probe depending on whether superficial structures (e.g. 10MHz) or deep structures (e.g. 5MHz) are being evaluated</td>
</tr>
<tr>
<td>Power</td>
<td>The machine should be powerful enough to image the proximal suspensory ligament using the optimal frequency and gain settings. High power settings decreased the signal to noise ratio.</td>
</tr>
<tr>
<td>Shades of grey</td>
<td>Musculoskeletal imaging benefits from interpretation of relatively subtle changes in the shades of grey, so that the maximal number of shades (256) provides the best quality images</td>
</tr>
<tr>
<td>Gain controls</td>
<td>The ability to adjust the gains throughout the image enables the operator to obtain an even grey throughout all depths of the image.</td>
</tr>
<tr>
<td>Focal zones</td>
<td>Multiple and selectable focal zones allow the image to be optimised for particular regions of the image (e.g. superficial digital flexor tendon (superficial) or suspensory ligament (deep))</td>
</tr>
<tr>
<td>Stand-off pad or fluid offset</td>
<td>As the superficial digital flexor tendon is separated from the probe by only 1-2 mm of skin in some horses, a separate stand-off pad (or integral fluid offset) is useful to avoid the superficial digital flexor tendon being within the emission artefact at the top of the screen, for easier orientation of the image when the skin surface is visible, and for increasing the width of the ultrasound ‘window’ as it conforms to the curved contours of the palmar aspect of the limb.</td>
</tr>
<tr>
<td>Storing of images</td>
<td>ESSENTIAL. It allows comparison for subsequent examinations and is essential in cases of legal action. Scans are best stored digitally as it also allows easy retrieval and/or transfer via the internet for second opinion.</td>
</tr>
<tr>
<td>Keyboard</td>
<td>An alphanumeric keyboard is ideal not only to enter case details but also to add relevant information such as limb, level of scan, and current exercise status.</td>
</tr>
<tr>
<td>Analysis software</td>
<td>A system which allows the measurement of a traced cross-sectional areas on the scans provides the most useful monitor of tendon healing during an increasing exercise programme.</td>
</tr>
<tr>
<td>Split screen</td>
<td>The ability to divide the screen in two so that both transverse and longitudinal scans of the same area can be displayed concurrently allows for more easy interpretation.</td>
</tr>
<tr>
<td>Cineloope</td>
<td>Although only present on the more expensive machines, this facility is well worth considering. In unco-operative horses, the freeze button can be pressed after the horse has moved and the cineloope used to replay the images to obtain the optimal relevant image. This facility can greatly reduce the time required for scanning horses which fidget.</td>
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Table 2 – The appearance of tissues on ultrasound

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Ultrasonographic appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendons/ligaments</td>
<td>Dotted internal architecture when the transducer lies at right angles to the structure (transverse) and a striated pattern when the transducer is parallel (longitudinal). Echoes probably more represent interfascicular tissue rather than collagen fibres. Ligaments may have deep and superficial parts with fibre orientation in different directions</td>
</tr>
<tr>
<td>Muscle</td>
<td>Hyperechogenic (bright) interfascicular septa with interspersed hypoechogenic (dark) muscle fibres. Fascial planes appear as strongly hyperechoic lines.</td>
</tr>
<tr>
<td>Cartilage</td>
<td>Anechogenic (black). The cartilage-synovial membrane/fluid and cartilage-bone interface give an appearance of “tram-lines”.</td>
</tr>
<tr>
<td>Bone</td>
<td>Highly reflective and produces acoustic shadowing deep to it.</td>
</tr>
<tr>
<td>Fat</td>
<td>Dependent on the connective tissue content of the fat. Frequently relatively hyperechogenic</td>
</tr>
<tr>
<td>Blood</td>
<td>Varies between hypoechogenic and hyperechogenic depending on whether the blood is static (hyperechogenic) or flowing (hypoechogenic). Superficially, veins will usually show some degree of collapse because of the pressure exerted by the transducer, while arteries will usually maintain their circular shape</td>
</tr>
<tr>
<td>Nerves</td>
<td>Echogenic. They can be difficult to identify but the larger ones have a coarse stippled pattern in transverse sections and a striated pattern in longitudinal views (similar to tendon but with a much coarser pattern)</td>
</tr>
<tr>
<td>Fluid</td>
<td>Anechogenic, often with acoustic enhancement (see section on artefacts) deep to it provided the collection of fluid is sufficiently large.</td>
</tr>
<tr>
<td>Pus</td>
<td>Depends on its consistency but will have a variable number of internal echoes +/- reverberation artefacts if gas is present</td>
</tr>
<tr>
<td>Gas/Air</td>
<td>Produces reverberation artefacts unless suspended in small bubbles which is characterised by numerous bright specular reflections. Often casts a combination of acoustic shadow with a central reverberation artefact. Tends to collect in the uppermost area of the cavity containing it.</td>
</tr>
<tr>
<td>Foreign bodies</td>
<td>Usually strongly hyperechogenic and produce either acoustic shadowing (e.g. wood; fig. 10) or reverberation artefact beneath (e.g. metal; fig. 12). Many foreign bodies (especially metal) have a very thin echo at its surface (cf. bone)</td>
</tr>
</tbody>
</table>
Figure 1 – Diagrammatic representation of ultrasonographic anatomy of the metacarpal region. (from The Athletic Horse - Diagnostic Imaging in the athletic horse: Musculoskeletal ultrasonography – Smith RKW and Webbon PM))
(a) Transverse images
(b) Longitudinal images

**Key**

SDFT - Superficial digital flexor tendon
DDFT - Deep digital flexor tendon
ALDDFT - Accessory ligament of the deep digital flexor tendon (Inferior check ligament)
SL - Suspensory ligament
MCP jt. - Metacarpophalangeal joint
Figure 2 – Diagrammatic representation of ultrasonographic anatomy of the pastern region.
(from Current Therapy in Equine Medicine 4 – Soft Tissue Injuries of the Pastern – Smith, R.K.W., and Webbon, P.M.)