Ultrasonographic examination of the palmar/plantar aspect of the fetlock in the horse: Technique and normal images

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Summary

The purpose of this paper is to present a comprehensive ultrasonographic technique to image the palmar/plantar aspect of the fetlock in the horse, from the manica flexoria (MF) down to the base of the proximal sesamoid bones (PSBs) and to describe the normal images. Ultrasonography, in combination with radiography, is the technique of choice to identify and document tendon and ligament injuries in routine practice and has been shown adequate for evaluating the palmar/plantar aspect of the fetlock. Detailed descriptions of transverse and longitudinal sections performed on the weightbearing or flexed limb are provided, as well as the technique for dynamic examination of the area. A thorough knowledge of detailed ultrasonographic anatomy is critical to identify abnormal images and establish an accurate diagnosis of palmar/plantar fetlock injuries.

Introduction

The equine fetlock undergoes high biomechanical stresses during locomotion, especially during the intermediate part of the stance phase, causing tremendous forces on the bones and soft tissues. There is marked, fast and repeated hyperextension of the fetlock in racehorses, whereas it is a slower movement with high load at jump reception in showjumpers. These stresses are responsible for lesions involving the different structures of the fetlock (Denoix 1993; Denoix et al. 1996, 2002; Richardson 2003; Bramlage 2009a,b).

Osteoarticular lesions of the metacarpal/metatarsophalangeal (MP) joint are common features of fetlock pathology and are the most widely debated in the literature. However, soft tissue lesions of the palmar/plantar aspect of the fetlock are not rare and must be taken into account when investigating distal limb lamenesses. Ultrasonography, in combination with radiography, is the technique of choice to identify and document tendon and ligament injuries in routine practice and has been shown adequate for evaluating the palmar/plantar aspect of the fetlock (Denoix 1996; Schramme and Smith 2003; Denoix et al. 2004). Ultrasonography of the palmar/plantar aspect of the fetlock is indicated where there are physical signs (distension of the digital sheath, thickening of the palmar/plantar profile), concurrent soft tissue lesions (e.g. distal metacarpal/metatarsal tendinopathy, suspensory distal branch injuries) or MP arthropathy (Denoix et al. 2002). More specific indications include a positive distal metacarpal/metatarsal nerve block, abnormal radiographic findings of the proximal sesamoid bones (PSBs) and increased radiopharmaceutical uptake over the palmar/plantar fetlock area on nuclear scintigraphy (Denoix et al. 2002).

Lesions of the MP joint have been widely documented using histology (Denoix et al. 1990; Drum et al. 2007), radiography (Berthier 1999; Jacquet et al. 2006; Morgan et al. 2006; Vanderperren and Saunders 2008), nuclear scintigraphy (Foreman et al. 2002; Weekes et al. 2004;...
Jacquet et al. 2006), magnetic resonance imaging (MRI) (Martinelli et al. 1996, 1997; Zubrod et al. 2004; Mair et al. 2005; Jacquet et al. 2006), computed tomography (Morgan et al. 2006; Drum et al. 2007; Vanderperren et al. 2008) and ultrasonography (Denoix 1993; Denoix et al. 1996, 2002); several papers have also described tenoscopy of the digital sheath (Wright and McMahon 1999; Wilderjans et al. 2003; Edinger et al. 2005; Smith and Wright 2006; Owen et al. 2008). In the past decade, less emphasis has been placed upon the ultrasonographic examination of the palmar aspect of the fetlock.

The purpose of this paper is to present a comprehensive ultrasonographic technique to image the palmar/plantar aspect of the fetlock from the manica flexoria (MF) to the base of the PSBs and to describe the normal images.

**Basic anatomy**

The detailed anatomy of the palmar/plantar aspect of the fetlock has previously been widely described (Denoix 1994a, 2000; Barone 2000; Cauvin 2003; Schramme and Smith 2003). The palmar/plantar annular ligament (PAL) lies immediately beneath the skin and subcutaneous tissue (Fig 1). It is a very thin (less than 1 mm thick) fibrous structure stretched across the palmar/plantar aspect of the superficial digital flexor tendon (SDFT). The PAL inserts on the palmar/plantar borders of the PSBs and is continuous with the lateral and medial borders of the palmar/plantar ligament (PL) (Fig 1). Dorsal to the PAL, the flexor tendons are surrounded by the digital sheath (DS), which contains very little fluid in the normal horse. Palmarly/plantarly, the DS presents a thin mesotendon.
connecting the SDFT sagittally to the PAL. The SDFT is flat, crescent-shaped and becomes progressively wider lateromedially. Proximally, the SDFT provides a fibrous ring, the MF, emanating from its lateral and medial borders and encircling the deep digital flexor tendon (DDFT) (Denoix 1994a, 2000; Barone 2000; Cauvin 2003; Schramme and Smith 2003). The MF extends over 30 mm from the most distal part of the metacarpal/metatarsal region down to the apex of the PSBs; it is thicker proximally and becomes thinner distally. At the level of the PSBs, the SDFT borders are slightly collateral to the DDFT borders and in close contact with them. In the distal metacarpal/metatarsal region, the DDFT is oval-shaped and becomes slightly wider and triangular distally, at the palmar/plantar aspect of the fetlock. Together with the MF, it slides on the proximal scutum, composed of the palmar (intersesamoidean) ligament (PL) and the 2 PSBs (Denoix 1994a, 2000; Denoix et al. 1997; Barone 2000) (Fig 1). The PL or intersesamoidean ligament is a strong, sagittal fibrocartilaginous structure inserting on the axial aspect of each PSB (facies flexoria or flexor surface). In the sagittal plane, the PL is thick and fills the space between the PSBs; it is much thinner laterally and medially at its insertions on the bones (Denoix et al. 1997; Barone 2000; Denoix 2000) (Fig 1). Proximally, the PL extends between the 2 branches of the suspensory ligament (BSL), preventing contact between the metacarpal/metatarsal condyle (MC) and the flexor tendons during hyperextension of the fetlock (Denoix et al. 1997). Distally, at the level of the base of the PSBs, the PL gives attachment to the straight sesamoidean ligament. The dorsal bone limit of the area is represented by the palmar/plantar aspect of the distal metaphysis of the third metacarpal/metatarsal bone and sagittal ridge of its condyle, distally. A thin layer of articular cartilage covers the subchondral bone of the MC (Denoix 1994a, 2000; Denoix et al. 1997; Barone 2000) (Fig 1). The proximopalmar/plantar synovial recess of the MP joint is seen proximal to the PSBs, close to the vasculoconnective space between the BSL.

**Equipment**

Since all the structures are superficial, basic ultrasonographic equipment is sufficient to scan the palmar/plantar aspect of the fetlock. A 7.5 MHz linear probe used with a 5 mm thick stand-off pad is all that is required. Higher frequency probes (10–12 MHz) can provide increased detail of the structures, although some horses with thicker skin may be difficult to examine with this kind of transducer because of the increased ultrasound attenuation. The hair is clipped from the distal quarter of the palmar/plantar metacarpal/metatarsal region down to the base of the PSBs. The clipping extends slightly laterally and medially in order to move the probe on the sides and perform the palmaro/plantarocollateral transverse sections. The skin is then soaked with hot water and covered with coupling gel.

**Technique and normal images**

With the limb bearing weight, the palmar/plantar aspect of the fetlock is imaged with a combination of transverse and longitudinal sections, using palmar/plantar and oblique palmaro/plantarocollateral approaches. This procedure can be repeated on the flexed limb. The examination is completed by carrying out a dynamic evaluation of tendon and ligament mobility with the limb flexed (Genovese et al. 1987; Denoix et al. 1997, 2002; Pasquet et al. 2007). The anatomical and ultrasonographic appearance of the palmar/plantar aspect of the fetlock varies as one moves distally. Four levels are distinguished in the following technical description: A) the level of the MF, proximal to the PSBs, B) apex of the PSBs, C) body and flexor surfaces of the PSBs and D) base of the PSBs (Fig 2). The angle of the probe should at all times be perpendicular to the structure under examination, thereby ensuring optimal echogenicity. Comparison between symmetrical structures and contralateral limbs should be performed routinely, especially to detect minimal changes (Denoix 1996). The ultrasonographic diagnosis of soft tissue injuries is based on the evaluation of several criteria i.e. size, shape, echogenicity, architecture and entheses (Denoix 1994b, 1996).

**Fig 2:** Schematic representation of the palmar aspect of the fetlock showing the different levels of ultrasonographic transverse sections (A–D). A. Transverse section at the level of the manica flexoria; A’ and A”. Oblique transverse sections at the same level (negative images); B. Transverse section at the level of the apex of the PSBs; C. Transverse section at the level of the body of the PSBs; D. Transverse section at the level of the base of the PSBs.
1. Weightbearing limb: transverse sections

a. Palmar/plantar approach

**Level A**

This transverse scan is performed slightly proximal to the apex of the PSBs (Figs 2 and 3). At this level, the MF is thick and in direct contact with the proximal part of the PL, protruding between the BSL. The dorsal limit of the ultrasonographic image is made by the palmar/plantar aspect of the distal metaphysis of the third metacarpal/metatarsal bone, which appears as a regular and thin hyperechogenic line. Proximally to the PL, hypoechochogenic vasculoconnective tissue, synovial membrane of the proximopalmar/plantar recess of the MP joint and the dorsal proximal recess of the DS fill the space between the PL, BSL and metacarpal/metatarsal bone. A small amount of fluid is frequently seen in the DS and is usually considered as not significant. At this level, all tendinous and ligamentous structures have the same homogeneous echogenicity, which makes their separate evaluation difficult. By tilting the probe proximally or distally (see A and A" on Fig 2), the flexor tendons become hypoechochogenic (the beam is not perpendicular to their fibres anymore), whereas the MF remains echogenic (its fibres are organised in a rather transverse pattern) (Fig 3). With this ‘off incidence’ or ‘negative’ image, more precise definition and delineation of the MF is achieved (i.e. thickness, shape, margins); it can also highlight abnormal echogenic spots or areas in the flexor tendons. This procedure - positive/negative images - can be repeated several times at each level of section.

**Level B**

At the level of the apex of the PSBs (Figs 2 and 4), the MF appears as a very thin echogenic layer surrounding the DDFT. The PAL can already be observed at the palmar/plantar aspect of the flexor tendons; sagitally, it appears as a poorly-defined echogenic layer and becomes hypoechochogenic collaterally (laterally and medially). The PL still very thick sagitally (12-17 mm), becomes thinner at its insertions on the lateral and medial flexor surfaces of the PSBs; those surfaces appear at this level as 2 short and slightly convex hyperechogenic lines, casting clean acoustic shadows dorsally. All soft tissue structures have the same echogenicity, but the flexor tendons present a dot pattern of architecture while the PAL and PL present a linear pattern. The most dorsal hyperechogenic limit is now represented by the most proximal part of the MC sagittal ridge, covered by a thin layer of anechogenic articular cartilage.

**Level C**

At this level (Figs 2 and 5) the SDFT borders are more prominent compared to the DDFT ones. The particular pattern of echogenicity of this tendon can be accurately assessed with a high resolution probe. With an oblique orientation of the beam, the negative image of the SDFT shows a typical 3-layer architecture, with 2 palmar/plantar and dorsal echogenic fibrocartilaginous layers separated by a thicker hypoechochogenic fibrous one. The precise visualisation of the palmar/plantar layer is critical, as it is the convex nature of the ligament. This artefact can be used to the clinician’s advantage: the contrast between the relatively hypoechochogenic collateral parts of the PAL and the greater echogenicity of the surrounding structures enables its thickness and margins to be identified and assessed. This cannot be done as easily in the sagittal...
plane where the PAL is of the same echogenicity as the adjacent palmar/plantar and dorsal structures.

At the level of the PSBs, the DDFT is oval-shaped, with smooth and well defined borders; its echogenicity is slightly greater than that of the SDFT, which has a more defined fibrillar architecture. The dorsal convex surface of the DDFT is in direct contact with the palmar/plantar concave surface of the PL. The PL is echogenic sagittally and fills the space between the DDFT and hyperechogenic flexor surfaces of the PSBs as well as the sagittal ridge of the MC. Its thickness decreases distally and collateral. The space between the 2 PSBs can be evaluated and compared to the contralateral one; the minimum distance varies from 3–6 mm. As the flexor surfaces are oblique, the collateral parts of the PL appear less echogenic than the sagittal part with a linear probe; this artefact can be reduced by the use of a convex probe, thanks to its wide diverging trapezoidal beam. Mild irregularities of the PSBs without echogenic spots deep into the subchondral bone are commonly seen and are anatomical variations that should not be mistaken for PL enthesopathy. Comparison with the contralateral limb is always useful.

Level D

At the level of the base of the PSBs (Figs 2 and 6), the PAL is very thin and more difficult to delineate than proximally. The flexor surfaces of the PSBs appear as 2 convex hyperechogenic lines covered palmarly/plantarly and axially by the PL and abaxially by the beginning of the oblique sesamoidean ligaments (lateral and medial). The dorsal hyperechogenic limit is represented by the most distal part of the MC sagittal ridge, covered by a thin layer of anechogenic articular cartilage. To obtain maximal echogenicity of the flexor tendons at this level the probe must be tilted proximally, because of the marked convexity of the most distal aspect of the palmar/plantar fetlock.

b. Palmaro/plantarocollateral approaches

In transverse sections, as the palmar/plantar aspect of the fetlock is convex and rather narrow, full contact between the probe and skin cannot be established on a single image, even with a soft acoustic pad. Placing the probe collateral completes the imaging of the area and provides a better representation of tendons’ margins and ligaments’ insertions (Figs 7a and b).

Level A

Proximal to the PSBs, the lateral border of the MF can be imaged by shifting the probe palmaro/plantarolaterally; this part of the MF is frequently injured and should be examined carefully. The same procedure is repeated palmaro/plantaromedially to examine the medial border (Fig 7a).

Levels B, C and D

At the level of the PSBs, the lateral and medial insertions of the PAL are scanned separately using collateral approaches: they appear echogenic and insert on the smooth hyperechogenic palmar/plantar borders of the PSBs (Fig 7b). By shifting the probe slightly more, the ultrasound beam becomes perpendicular to the opposite flexor surface, which appears brightly hyperechogenic; the corresponding collateral part of the PL takes on a homogeneous echogenic appearance. Specific imaging of the medial part is achieved by placing the probe palmaro/plantarolaterally, directing the beam in a dorsomedial direction and vice versa. Tilting the probe this way allows complete imaging of the PL. This approach is indicated particularly when enthesopathy is suspected.

2. Weightbearing limb: longitudinal sections

At the palmar/plantar aspect of the fetlock, transverse sections are the most appropriate ones to establish a diagnosis of tendon or ligament injury. They can be complemented by longitudinal scans in order to obtain a topographical representation of the lesion(s) and a detailed documentation of the clinical case.
a. Sagittal sections

Sagittal sections are performed using a palmar approach (Fig 8).

Levels A and B

Proximal to the PSBs, as the ultrasound beam is entirely perpendicular to the flexor tendons, they appear homogeneously echogenic with a well defined parallel architecture. The MF is difficult to delineate in longitudinal sections. The proximal suprasesamoidean part of the PL is seen as a poorly echogenic structure extending proximally. The vasculoconnective space and synovial membrane proximal to it appear heterogeneous and hypoechoic. Dorsally, soft tissues are limited by the hyperechoic bone surface of the metacarpal/metatarsal metaphysis and condyle.

Levels C and D

At these levels, the palmar/plantar profile of the fetlock and underlying structures becomes convex, particularly at the most distal area (level D). The flexor tendons appear hypoechoic distally as the ultrasound beam is not entirely perpendicular to their fibres anymore. To avoid this artefact and obtain diagnostic images, the angle of the probe must adapt to the convexity of the region. The sagittal part of the PL appears as a thick structure of moderate echogenicity, between the DDFT and sagittal ridge of the MC. The beginning of the straight sesamoidean ligament can be imaged just distal to the base of the PSBs, inserting on the PL. The dorsal limit of the image is represented by the MC sagittal ridge, with its anechoic layer of articular cartilage covering the hyperechoic subchondral bone.

b. Parasagittal sections

Parasagittal sections are useful for evaluating lesions of the proximal scutum (level C) and especially the flexor surfaces of the PSBs. On successive lateral or medial parasagittal sections, moving the probe obliquely, the PL becomes thinner and the flexor surface more convex and superficial (Fig 9).

3. Flexed limb: standard examination

The same approaches and sections as described above can be performed on the flexed limb, placing the dorsal
aspect of the fetlock on the operator’s knee and flexing the MP joint at various degrees. The wider contact surface provides a better visualisation of the tendons and ligaments borders as well as the MF contours. When the fetlock is flexed, the suspensory apparatus is relaxed, causing the PSBs and the PL to move palmarly/plantarly and allowing synovial fluid to fill the proximopalmar/plantar recess of the MP joint (Fig 10). On sagittal sections, a precise delineation of the dorsal border of the PL as well as the palmar cartilage and subchondral bone of the MC can be achieved. Moreover, as the tendons are relaxed, some lesions are difficult, if not impossible, to see on the standing limb - as longitudinal tears of the DDFT - can be detected. This procedure is more difficult to carry out on the hindlimb.

4. Flexed limb: dynamic examination

In order to evaluate the functional relationship between the flexor tendons and adjacent ligaments (PAL and PL), a real-time dynamic examination of the palmar aspect of the fetlock can be carried out on the flexed limb, especially when a chronic tenosynovitis of the DS has been identified (Denoix et al. 1997, 2002). After placing the dorsal aspect of the fetlock on the operator’s knee, the probe is positioned sagittally on the palmar/plantar aspect of the area. Slow movements of flexion and extension of the fetlock are performed. In normal horses, the flexor tendons slide in the same direction and at the same speed, except for a slight asynchrony at the maximal angulation of each movement. When a constant asynchronous movement of the tendons is observed, adhesions should be suspected (Denoix et al. 1997). The most frequent adhesions develop between the SDFT and the PAL, caused by a thickened and less elastic mesotendon (chronic proliferative synovitis); rarely, adhesions between the DDFT and the PL can be observed.

Discussion

Radiography has historically been the only imaging modality used on horses presenting with clinical signs of fetlock pathology; however, this technique has major limitations in the diagnosis of soft tissue lesions (Denoix 1996; Denoix and Busoni 1998). Radiography can still provide useful complementary information on the palmar/plantar aspect of the fetlock with respect to lesions of the PSBs (BSL, PL or PAL enthesopathy) or to detect soft tissue mineralisations. In particular, the proximodistal projection (PSBs skyline) is useful to assess the flexor surfaces of the PSBs (Vanderperren and Saunders 2008). Contrast radiography has been used to detect adhesions or masses within the DS (Hago and Vaughan 1986; Dik et al. 1995), but its diagnostic value has been overcome by other imaging modalities such as ultrasonography and tenoscopy.

As the palmar/plantar fetlock is mainly composed of tendons and ligaments, ultrasonography is the technique of choice for its evaluation in routine practice (Denoix 1996; Denoix et al. 2004; Thomas et al. 2009). When clinical signs suggest a lesion of the palmar/plantar aspect of the fetlock, a complete ultrasonographic examination should be undertaken by combining palmar/plantar and collateral approaches on the weightbearing and flexed limb and a dynamic examination on the flexed limb; the dynamic examination can be difficult to carry out on
Some horses, especially on hindlimbs, but provides critical indications for the prognosis. Palmaro/plantarocollateral approaches are recommended to examine the borders of tendons and ligaments without edge shadowing artefacts (Edinger et al. 2005), especially as degenerative lesions of the MF and flexor tendons occur more frequently at their lateral aspect (Barr et al. 1995; Wright and McMahon 1999; Wilderjans et al. 2003; Edinger et al. 2005). Moreover, comparison between symmetrical structures and contralateral limbs increases the diagnostic sensitivity and specificity (Denoix 1996). Still, accurate diagnostic ultrasonography requires a skilled and experienced operator with an in-depth knowledge of the anatomy and normal images (Denoix et al. 1996). Correct positioning and angulation of the probe are critical to obtain images of diagnostic value and limit artefacts or misinterpretation (Denoix et al. 1996).

Particular attention must be drawn on the specific ultrasonographic examination of the PAL. As previously stated, this ligament is very thin and appears as a poorly defined band between the subcutaneous tissue and SDFT. One must bear in mind that between the epidermis and the PAL there is quite a thick layer (approximately 2 mm) of dermis and subcutaneous tissue (Dik et al. 1991). These structures, together with the palmar layer of the SDFT or a thickened mesotendon, are commonly mistaken for the PAL; this can lead to an overestimation of the ligament thickness and an incorrect diagnosis of PAL desmitis. The PAL thickness is better assessed parasagittally on transverse section (rather than in the sagittal plane) where its low echogenicity differentiates it from the surrounding structures. In chronic tenosynovitis of the DS, the PAL undergoes a certain amount of elongation because of the marked chronic fluid pressure. In our experience, when scanning those horses, synovia and/or membrane (mesotendon) can be seen between the PAL and the SDFT, indicating that there is no constriction in this area, contrary to the commonly accepted concept of a constriction syndrome. The typical notch described in those cases is related to a decreased amount of distension at the level of the PAL, which is seen wherever a retinaculum is located.
[e.g. tenosynovitis of the long digital extensor at the dorsal aspect of the hock]. In this context, ultrasonography has proved to be a key diagnostic tool as it enables an accurate assessment of the injured structures prior to undertaking the appropriate treatment (i.e. sheath injection, tenoscopy, corrective shoeing).

Tenoscopy of the DS is indicated as a diagnostic procedure complementary to ultrasonography on cases presenting with tenosynovitis of the DS (Thomas et al. 2009). This is an invasive modality requiring general anaesthesia, but it has the advantage of allowing treatment to be performed immediately (Wilderjans et al. 2003). Contrary to ultrasonography, the inner architecture of tendons and ligaments cannot be assessed with tenoscopy, but this technique is more sensitive for differentiating adhesions, longitudinal tears (LTs) and superficial fibrillations (Cauvin 2003; Edinger et al. 2005; Smith and Wright 2006; Thomas et al. 2009). Floating echogenic material contiguous with the lateral or medial border of the DDFT is commonly seen at the ultrasonographic examination of DS with chronic tenosynovitis; this material often reveals to be surface fibrillation of the tendon at tenoscopy, frequently associated with a LT deeper in the tendon (Wright and McMahon 1999; Wilderjans et al. 2003; Edinger et al. 2005; Smith and Wright 2006). Fibrillations can be identified as well on the MF, SDFT and PL; LTs are sometimes seen on the MF and SDFT. Using the palmar/plantar and collateral approaches on a flexed limb can improve the ultrasonographic diagnosis of LTs, but ultrasonography remains less sensitive than tenoscopy for detecting those fissures (Wilderjans et al. 2003; Thomas et al. 2009).

Longitudinal tears of the flexor tendons can be detected on MRI images, but small fibrillations and focal area of fibrosis are more difficult to see. High field as well as low field units have proved to be sensitive for the examination of bones as well as soft tissues of the equine digit (Mair et al. 2003; Jacquet et al. 2006; Dyson and Murray 2007; Murray et al. 2009; Thomas et al. 2009). Both have high diagnostic value, but low field standing MRI is more affordable and less invasive; perfect stillness of the limb is required to obtain valuable images of the palmar/plantar aspect of the fetlock. High field scanners require general anaesthesia of the patient but provide images of a better accuracy and are particularly indicated when a lesion of the PL is suspected. The architecture of this ligament can be difficult to assess with combined imaging, including ultrasonography, MRI and tenoscopy.

Over the past few years, interest has grown in using computed tomography (CT) as an alternative to MRI for evaluation of soft tissues of the equine digit (Eliashar et al. 2006; Vanderperren et al. 2008; Puchalski et al. 2009). New protocols, including the use of intra-arterial contrast medium infusion (Puchalski et al. 2009), have been established to improve the diagnostic value of this modality, but it remains so far less effective than MRI for detecting soft tissue injuries. Moreover, the procedure must be performed under general anaesthesia; standing CT has been developed, but is not suitable yet for soft tissue evaluation (Desbrosse et al. 2008).
As the diagnosis and follow-up can be done in the field with portable machines, ultrasonography is the technique of choice for examination of the palmar/plantar aspect of the equine fetlock. It is a safe and noninvasive technique that can be easily and repeatedly performed in the field. Ultrasonography is a valuable diagnostic, prognostic and therapeutic tool. Therefore, we consider that ultrasonography, together with complementary radiographic examination, should be routinely employed as a first approach for the diagnosis and documentation of fetlock injuries, before considering other imaging modalities.

Authors’ declaration of interests

No conflicts of interest have been declared.

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