Title

Sonographic Anatomy of the Equine Palmar Distal Digit

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Abstract

Although ultrasonography is widely used in equine orthopaedics, its use in the distal portion of the digit is still limited. The purpose of this descriptive study was to document the normal ultrasonographic appearance of the distal palmar digital area imaged at the distal pastern and between the bulbs of the heels. Ultrasonographic images were obtained with a 7.5 MHz microconvex transducer in 10 fresh equine cadaver forelimbs and 5 sound horses. Sagittal, parasagittal and transverse images were obtained from the proximal aspect of the middle phalanx to the distal sesamoid bone. Anatomical sections were obtained from 5 cadaver specimens to correlate sonographic appearance with anatomical findings. The remaining cadaver limbs were dissected to confirm normalcy. Ultrasonographic exams were possible on all digits but distal images were more difficult to obtain in digits with long heels. Bony structures (palmar surface of the middle phalanx and proximal border of the distal sesamoid bone) and soft tissue structures (deep digital flexor tendon, digital tendon sheath, proximal palmar recess of the distal interphalangeal joint, proximal recess of the podotrochlear bursa, collateral sesamoidean ligaments) identified on the anatomical slices, were seen on the matched ultrasonographic slices. Ultrasonography provides good anatomical details of the palmar distal digit. The images of this study will serve as a reference for clinical studies on ultrasonography of the palmar distal digit.

Key words: equine, ultrasonography, pastern, digit, anatomy.

Text

Introduction

Soft tissue injuries are reported as a cause of digit pain [1]. Magnetic resonance (MR) imaging is not available as a routine imaging technique for horses and is only available in referral centers. Furthermore, MR examination often requires general anesthesia and is an expensive method. Ultrasonography, on the other hand, is recognised as a routine, non invasive imaging technique and provides detailed information about soft tissue injuries [2, 3, 4, 5, 6, 7].

Ultrasonography is used widely for evaluation of the metacarpal and pastern regions. The use of ultrasonography to image the distal portion of the digit has been described [8, 9, 10]. However, its routine use in the distal digital area is still limited [11]. The purpose of this study was to document the normal ultrasonographic (US) appearance of the palmar distal digital area imaged through the distal pastern and between the bulbs of the heels and to provide a detailed description of the reference images obtained with a 7.5 MHz microconvex transducer.

Materials and Methods

Technique

The distal digits were scanned through the distal pastern and between the bulbs of the heels with a microconvex transducer operating at 7.5 MHz (Aloka 3500 - Aloka prosound SSD-3500, Mitaka-shi, Tokyo, Japan). The area was prepared by fine clipping and washing the skin with warm water. Contact transmission gel was applied in order to provide a good coupling between the transducer and the wet skin surface. A hand-held stand-off pad was sometimes used to enhance the contact surface and to guarantee an airfree acoustic interface between probe and skin, especially in digits where the heels were long. The US examinations on live horses were first performed on the weight-bearing limb (Fig. 1) and then with the foot held up off the ground (Fig. 2). In this position, the toe was placed firmly on the leg of the person holding the horse's digit during the examination to obtain some extension of the

fetlock and distal interphalangeal joint (DIPJ). The scanned area corresponded to the palmar aspect of digit from the middle phalanx to the area between the bulbs of the heels. Transverse sections were made by progressive movement of the probe from the proximal to the distal limit of this area. Longitudinal ultrasound scans were obtained in the sagittal plane and in parasagittal oblique planes, with the transducer footprint angled medially and laterally (palmaroaxial-dorsoabaxial planes).

Ultrasonographic Images and Anatomical Specimens

Five healthy horses, with no history of lameness and without local swelling or joint distension nor abnormal radiological findings in the pastern or the foot, were scanned to document normal, transverse and longitudinal US images of the palmar distal digit. Ultrasonographic images were recorded at a minimum of three levels in transverse planes (middle phalanx, proximal palmar recess of the DIPJ and distal sesamoid bone - DSB) and in three longitudinal planes (sagittal plane, dividing the digit in 2 nearly equal halves, and through each part of the deep digital flexor tendon - DDFT) (Fig. 3). These images were recorded and compared to gross anatomical sections obtained in the same or similar planes.

Ten fresh equine cadaver forelimbs, considered sound because of their normal appearance at inspection, palpation and radiographs, were selected from an abattoir. The DIPJ, the podotrochlear bursa and the digital tendon sheath were injected with coloured Xantopren® (Heraeus Kulzer, Dormagen, Germany), a silicon based precision condensation curing impression material, to highlight the anatomy and the topography of these structures. The Xantopren® was dissolved in heptane. The Activator Universal for the Xantopren® preparation was also dissolved in heptane. The Activator Universal was added to the Xantopren®. The proportion was: 10ml of heptane and 0,75g of Activator Universal for 5g of Xantopren®. The polymerisation was done within 4 minutes at +23°C. The Xantopren® L blue was injected in DIPJ. The Xantopren® H green was injected in the podotrochlear bursa. The Xantopren® M mucosa was injected in the digital tendon sheath. The limbs were frozen

at -20°C. Longitudinal and transverse anatomical sections (10-15 mm thick) were obtained from five cadaver specimens at the level of the US section, to correlate the sonographic appearance with the anatomical findings. The remaining cadaver limbs were dissected to confirm normalcy and to establish the anatomical relationships.

Results

Transverse Reference US Images

The transverse reference images presented are obtained at three levels: 1. at the level of the proximal third of the middle phalanx, 2. at the level of the proximal palmar recess of the DIPJ, 3. and at the level of the proximal third of the DSB (Fig. 3).

Level 1: US images obtained at the level of the proximal third of the middle phalanx (Fig. 4a and 4b).

Palmar to dorsal, under the skin, is the digital cushion which appears as an echoic, speckled band. A thin linear hypoechoic line may be seen between the digital cushion and the DDFT and corresponds with the distal digital annular ligament. At this level, the DDFT has two portions: the palmar part is fibrous, the dorsal part is fibrocartilaginous. On the US images the two parts may be differentiated: the palmar fibrous part is speckled hyperechoic, while the dorsal fibrocartilaginous part is hypoechoic. The DDFT is surrounded by an anechoic line, more visible at the dorsal aspect of the tendon corresponding to the digital tendon sheath. The most dorsal structure is the palmar surface of the middle phalanx which appears as a hyperechoic line with acoustic shadowing dorsally.

Level 2: US images obtained at the level of the proximal palmar recess of the DIPJ (Fig. 5a and 5b).

The digital cushion is thicker at this level and becomes bilobed. The distal digital annular ligament is still present between the digital cushion and the DDFT as a thin hypoechoic structure. At this level, the DDFT is thinner and the separation into 2 lobes is more evident.

The DDFT is completely fibrous at this level and becomes homogeneously hypoechoic because of the oblique direction of the ultrasound beam in relation to the axis of the tendon fibres. Dorsal to the DDFT, an anechoic band corresponds to the proximal recess of the podotrochlear bursa. Dorsal to the bursa, the collateral sesamoidean ligaments appear as a slightly bilobed hyperechoic band which palmarly closes the anechoic proximal palmar recess of the DIPJ. The hyperechoic palmar surface of the middle phalanx represents the deepest limit of the image.

More distal transverse images are difficult to obtain, especially in horses with long heels. By holding the foot up off the ground (Fig. 2), transverse images can be obtained more distally than when the limb is weight-bearing.

Level 3: US images obtained at the level of the proximal third of the DSB (Fig. 6a and 6b). The digital cushion, the distal digital annular ligament and the DDFT are still visible at this level. The podotrochlear bursa is thinner and is sometimes seen as an anechoic line. Dorsal to it, the flexor surface of the DSB appears as a hyperechoic line with an acoustic shadow dorsally. Only the most proximal aspect of the flexor surface can be visualised with this approach.

Longitudinal Reference US Images

Longitudinal US images presented here are obtained in two planes: 1. sagittal plane, dividing the digit in two nearly equal halves, 2. parasagittal oblique plane (palmaroaxial – dorsoabaxial).

Section 1: US images obtained in the sagittal plane (Fig. 7a and 7b)

The palmar structure deep to the skin is the digital cushion which has the typical hyperechoic speckled appearance. The distal digital annular ligament may be seen as a hypoechoic line deep to the digital cushion. The DDFT is seen as an echoic band that becomes hypoechoic in the distal part because of the orientation of its fibres in relation to the US beam. The DDFT

can be followed until the proximal third of the DSB in most horses. The tendon is surrounded by the digital tendon sheath, visible at the dorsal part of the tendon as an anechoic line. The digital tendon sheath ends distally at the level of the flexor tuberosity of the middle phalanx. Distal to the digital tendon sheath, a hypoechoic pouch, which corresponds to the podotrochlear bursa, is seen dorsal to the DDFT and proximal to the DSB proximal border. Dorsal to these structures, the proximopalmar recess of the DIPJ appears as an anechoic pouch in contact with the palmar hyperechoic surface of the middle phalanx. A triangular echoic structure, attached to the DSB proximal border, is visible between the digital tendon sheath, the proximopalmar recess of the DIPJ and the podotrochlear bursa and represents the axial fibres of the collateral sesamoidean ligaments. In fact, each collateral sesamoidean ligament is attached distally on the proximal border of the DSB, mainly abaxially, but some fibres connect both ligaments along the proximal border of the DSB. The hyperechoic palmar surface of the middle phalanx is seen at the dorsal limit of the image. Between the two hyperechoic lines of the palmar cortices of the middle phalanx and the DSB, a thin anechoic gap represents the cartilage thickness of the articular surfaces of the DIPJ. Sometimes, a vessel (palmar rami of the digital vein) may be seen just palmar to the proximal third of the middle phalanx.

Section 2: US images obtained in the parasagittal oblique plane (Fig. 8a and 8b)

The imaged structures are the same than in sagittal plane. In the parasagittal plane, the collateral sesamoidean ligament and the DDFT appear thicker than in the sagittal plane. The proximal palmar recess of the podotrochlear bursa is slightly bigger on each side compared to the sagittal plane.

Discussion

Technique

The palmar surface of the distal digit is not flat especially between the bulbs of the heels and a good contact between the probe and the skin may be difficult to obtain. A fine clipping was

necessary to eliminate the artefacts caused by hair. The skin was washed with warm water to soften the skin and to improve the transmission. The contact area for successful imaging of the structures at the palmar distal digit is relatively small. A high pressure on the probe is necessary. The examinations on live horses were first performed on the weight-bearing limb and then on the foot held up off the ground. In this latter position, the images were of better quality if the toe of the horse was placed firmly on the leg of the person holding the horse's digit during the examination to obtain some digital extension. Transverse images could be obtained more distally using this technique. This examination was possible on every digit but it was more difficult in digits with long heels. Having the best visualisation of all structures on the same image was not easy in this area and the evaluation of all structures required sometimes taking images with a slight different obliquity.

Ultrasonographic Anatomy

Ultrasonographic images and regional anatomy correlated well in this study. The anatomical sections were mainly obtained in a plane parallel to the ground while the US images were transverse oblique images with a palmaroproximal – dorsodistal orientation. This explains the slight difference between the transverse anatomical sections and the transverse US images. For the same reason, the digital cushion was more visible on the anatomical sections than on the corresponding US images.

The distal digit showed no significant morphological or topographical variation on the US images in the cadaver horses and live horses. The main anatomical structures of the palmar distal digit were well seen to the proximal third of the DSB. Distal to this limit, the access was impossible through the palmar pastern. The transcuneal approach of the distal limb [9, 12, 13] should be used to complete this approach as it allows the evaluation of these more distal structures of the podotrochlear apparatus. However, even combining these two approaches, a part of the podotrochlear apparatus, mainly the middle third of the flexor surface of the DSB and the DDFT at this level, are not able to be evaluated in some horses. This blind area

depends on the hoof's conformation (long heels, quality and size of the frog[12]). In fact, when the heels are long, the structures to be imaged are deeper and therefore more difficult to access.

No measurement was included in this study because the plane of the section was not perfectly perpendicular or sagittal to the structures and depended mainly on the hoof's conformation. In this way, standard measurements like with MR images [14] were not possible.

Clinical Aspects

Soft tissue damages including collateral sesamoidean ligaments desmitis, DDFT tendinopathy are reported as a possible source of foot pain [1, 15, 16, 17]. The location of the tendinopathy in the foot seems to be mainly located at the level of the proximal aspect of the DSB and distal to the DSB in the region of insertion on the distal phalanx [1]. Concurrent distension of the podotrochlear bursa is common [1]. Desmopathy of the collateral sesamoidean ligament has been diagnosed by US [15]. Ultrasonography through the distal pastern and between the bulbs of the heels appears to be a good tool to routinely investigate and to follow up these soft tissue structures located in the distal digit proximal to the DSB. For the more distal lesion like in the insertion of the DDFT on the distal phalanx, a transcuneal approach [9, 12, 13] seems more appropriate if this lesion is not in the blind area. Because of the difficulty in obtaining measurements, the symmetry of the structures and the comparison with the contralateral foot seems to be the best way to evaluate these structures [11, 14].

Conclusion

This study describes and documents the normal US appearance of the palmar distal digital area imaged through the distal pastern and between the bulbs of the heels. A good knowledge of the US technique and anatomy is essential to realise this approach. The images of this study will serve as a reference for clinical US imaging studies of the palmar distal digit.

Legends

-Figure 1: Ultrasonographic examination of the equine palmar distal digit in standing position: position of the probe.

-Figure 2: Ultrasonographic examination of the equine palmar distal digit on the limb held up off the ground: position of the probe.

-Figure 3: Drawing of a sagittal section of the distal digit of a horse. Black lines (proximal to distal) show the levels at which the transverse ultrasound scans in Figures 4a, 5a, 6a were performed.

-Figure 4a: Transverse US image at the level of the middle phalanx which is showed on the Fig.3 as level 1 and Figure 4b: Transverse anatomical section at the level of the middle phalanx. The section plane is parallel to the ground and therefore slightly different than the scanning plane of Figure 4a. 1. skin, 2. digital cushion, 3. distal digital annular ligament, 4a. deep digital flexor tendon (fibrous part), 4b. deep digital flexor tendon (fibrocartilaginous part), 5. digital tendon sheath, 6. middle phalanx.

-Figure 5a: Transverse US image at the level of the proximal palmar recess of the DIPJ and collateral sesamoidean ligaments which is showed on the Fig.3 as level 2 and Figure 5b: Transverse anatomical section at the level of the proximal palmar recess of the DIPJ and collateral sesamoidean ligaments. The section plane is parallel to the ground and therefore slightly different than the scanning plane of Figure 5a. 1. skin, 2. digital cushion, 3. distal digital annular ligament, 4. deep digital flexor tendon, 6. middle phalanx, 7. proximal palmar recess of the distal interphalangeal joint, 8. collateral sesamoidean ligaments, 9. proximal recess of the podotrochlear bursa.

-Figure 6a: Transverse US image at the level of the DSB which is showed on the Fig.3 as level 3 and Figure 6b: Transverse anatomical section at the level of the DSB. The section plane is parallel to the ground and therefore slightly different than the scanning plane of Figure 6a. 1. skin, 2. digital cushion, 3. distal digital annular ligament, 4. deep digital flexor tendon, 9. proximal recess of the podotrochlear bursa, 10. distal sesamoid bone.

-Figure 7a: Sagittal US image at the palmar aspect of the middle phalanx and proximal aspect of the DSB and Figure 7b: Sagittal anatomical section at the palmar aspect of the middle phalanx and proximal aspect of the DSB. 1. skin, 2. digital cushion, 3. distal digital annular ligament, 4. deep digital flexor tendon, 5. digital tendon sheath, 6. middle phalanx, 7. proximal palmar recess of the distal interphalangeal joint, 8. collateral sesamoidean ligaments, 9. proximal recess of the podotrochlear bursa, 10. distal sesamoid bone.

-Figure 8a: Parasagittal oblique US image at the palmar aspect of the middle phalanx and proximal aspect of the DSB and Figure 8b: Parasagittal anatomical section at the palmar aspect of the middle phalanx and proximal aspect of the DSB. 1. skin, 2. digital cushion, 3. distal digital annular ligament, 4. deep digital flexor tendon, 5. digital tendon sheath, 6. middle phalanx, 7. proximal palmar recess of the distal interphalangeal joint, 8. collateral sesamoidean ligaments, 9. proximal recess of the podotrochlear bursa, 10. distal sesamoid bone.

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