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Magnetic resonance imaging evaluation of 264 horses with foot pain: The podotrochlear apparatus, deep digital flexor tendon and collateral ligaments of the distal interphalangeal joint

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Summary

Reasons for performing study: **To improve understanding of the interrelationships between injuries of the podotrochlear apparatus and deep digital flexor tendon (DDFT).**

Hypotheses: **There is a difference in frequency of different types of lesions at different anatomical sites of the DDFT. Lesions of the collateral sesamoidean ligament (CSL), distal sesamoidean impar ligament (DSIL), distal interphalangeal (DIP) joint and navicular bursa are seen in association with lesions of the navicular bone.**

Methods: **The magnetic resonance (MR) images of 264 horses with unilateral or bilateral foot pain were analysed and graded. Descriptive statistics were performed to establish the frequency of occurrence of DDFT lesion types at different anatomical levels, and lesions of the CSL, DSIL, navicular bursa, DIP joint and collateral ligaments (CLs) of the DIP joint. A Chi-square test was used to test for a difference in the proportion of navicular bone grades between limbs with and without DDFT lesions at each level, and to compare navicular bone grades for limbs with and without each of DSIL, CSL, navicular bursa or DIP joint lesions.**

Results: **Lesions of the DDFT occurred in 82.6% of limbs, occurring most commonly at the level of the CSL (59.4%) and the navicular bone (59.0%). Core lesions predominated at the level of the proximal phalanx (90.3%), whereas at the level of the CSL and navicular bone core lesions, sagittal splits and dorsal abrasions were most common. There was a positive association between DDFT lesions and navicular bone pathology involving all aspects of the bone. Lesions of the DSIL (38.2% limbs) were more common than those of the CSL (10.5%), but the presence of either was associated with abnormalities of the navicular bone, especially involving the proximal or distal borders and the medulla.**

Conclusions and clinical relevance: **There are close interactions between injuries of the components of the podotrochlear apparatus, the DDFT, the navicular bursa and the DIP joint. Further knowledge about the biomechanical risk factors for injury may have importance for both disease prevention and management.**

Introduction

Since the advent of clinical magnetic resonance imaging (MRI) the significance of soft tissue injuries of the digit has been well recognised. Lesions of the DDFT detected clinically, using MRI, have been described (Dyson *et al.* 2003a,b; Mair *et al.* 2003). The coexistence of injuries to the navicular bone and DDFT and other soft tissue injuries of the podotrochlear apparatus has been recognised clinically using MRI (Dyson *et al.* 2003a,b, 2005, 2006; Mair *et al.* 2003; Schneider *et al.* 2003; Martinelli and Rantanen 2005) and verified by *post mortem* examination (Busoni *et al.* 2005; Blunden *et al.* 2006a,b; Murray *et al.* 2006a,b). However to date there have been no detailed descriptions of the frequency of soft tissue injuries and their relationships with pathology of the navicular bone detected using MRI.

It was hypothesised that there would be a difference in frequency of different types of lesions at different anatomical sites of the DDFT and that lesions of the collateral sesamoidean ligament (CSL), distal sesamoidean impar ligament (DSIL), distal interphalangeal (DIP) joint and navicular bursa would be seen in association with lesions of the navicular bone.

The purposes of the study were to: describe in detail the proximodistal distribution of lesions of the DDFT and the types of lesion that occur at each site; document the frequency of injuries to the components of the podotrochlear apparatus and the collateral ligaments (CLs) of the DIP joint; and investigate relationships between lesions of structures of the podotrochlear apparatus and the DDFT.

Materials and methods

All horses were examined at the Centre for Equine Studies of the Animal Health Trust between January 2001 and December 2004. Horses selected for inclusion in this study had unilateral or bilateral forelimb lameness that was abolished by perineural analgesia of the palmar (abaxial sesamoid) nerves. The horses had been selected for MR examination because the results of clinical, radiographic, nuclear scintigraphic and ultrasonographic examinations did not conclusively explain the degree of lameness. Both forelimbs were examined using scintigraphy and MRI irrespective of whether lameness was unilateral or bilateral (Dyson and Murray 2007a,b).

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The MR images were subjectively evaluated prospectively by one of 2 trained analysts (R.M. or G.G.). The navicular bone was graded retrospectively by S.D. as described in Dyson and Murray 2007b. The DDFT was defined with respect to location and lesion type and an overall grade was assigned, defined as the presence or absence of a lesion distal to the metacarpophalangeal joint. The location of the DDFT was defined as: insertion, level of the DSIL, navicular bone, proximal aspect of the navicular bursa/CSL, proximal interphalangeal (PIP) joint and proximal phalanx. Lesion types were described as core, dorsal abrasion, parasagittal split or insertion. Each border of the navicular bone (palmar or flexor, distal, dorsal, proximal) and the medulla were graded separately (Dyson and Murray 2007b). The presence or absence of lesions of the DSIL, CSL, navicular bursa, DIP joint and CLs of the DIP joint was recorded.

Statistical analysis

Descriptive statistics were performed on all the data to establish the frequency of occurrence of DDFT lesion types at each level, and lesions of the CSL, DSIL, navicular bursa, DIP joint and CLs of the DIP joint. A Chi-square test was used to test for a difference in the proportion of navicular bone grades between limbs with and without DDFT lesions at each level, and to compare navicular bone grades for limbs with and without each of DSIL, CSL, navicular bursa or DIP joint lesions. All analyses were performed with statistical analysis software (Analyse-it) with a significance level of 0.05.

Results

Lesions of the DDFT were identified at one or more sites in 82.6% of limbs. Abnormalities of the DSIL were detected in 38.2% limbs, but only 10.5% had abnormalities of the CSL. Lesions of the medial and lateral CLs of the DIP joint were detected in 28.2% and 12.4% of limbs respectively. Lesions of the DIP joint and navicular bursa (generally effusion with or without synovial proliferation) were seen in 42.3% and 49.4% of limbs respectively. There were no differences between left and right limbs.

Lesions of the DDFT occurred most frequently at the level of the CSL and navicular bone, being present in 59.4% and 59.0% of limbs, respectively. Lesions at the level of the DSIL or insertion were less common (35.1% and 37.1% of limbs, respectively), followed by the level of the PIP joint (29.1% of limbs) and were least common at the level of the proximal phalanx (6.2% of limbs).

The types of lesions that predominated varied with the level of the DDFT lesion. At the level of the proximal phalanx core lesions of the DDFT predominated (28/31 lesions, 90.3%). At the level of the PIP joint core lesions (63/146 lesions, 43.1%), either alone (n = 49) or in combination with either dorsal abrasions or parasagittal splits, occurred with similar frequency to dorsal abrasions (59/146 lesions, 40.4%), either alone (n = 44) or in combination with core lesions or parasagittal splits. Parasagittal splits were less common (43/146 lesions, 29.5%). At the level of the CSL dorsal abrasions were most common (212/298 lesions, 71.1%), either alone (n = 176) or in combination with other lesions. Core lesions (70/298 lesions, 23.5%) or parasagittal splits (65/298 lesions, 21.8%) occurred with similar frequency, with 60% of core lesions as the sole lesion and 55% of parasagittal splits as the sole lesion. At the level of the navicular bone the pattern was similar, with dorsal abrasions the most common (174/296 lesions, 58.8%), followed by parasagittal splits (92/296 lesions, 31.1%) and core lesions (76/296 lesions, 25.7%). At the level of the DSIL classification of lesions type was more difficult, 51.7% of 176 lesions being dorsal abrasions and 43.2% unclassified. Lesion type was generally not classified at the insertion of the DDFT.

Association between navicular bone grade and lesions in soft tissue structures

Deep digital flexor tendon: When limbs with and without a DDFT lesion distal to the metacarpophalangeal joint were compared, there was no difference in the proportion of navicular bone grades for any region. However, the proportion of each navicular bone grade was significantly different when compared with lesions at specific regions of the DDFT, with a navicular bone *Grade 0* being relatively under-represented in the limbs with lesions and other grades being relatively over-represented for all comparisons. There was a difference in the proportions of navicular bone flexor border grades between limbs with and without DDFT lesions at the level of the navicular bone (P = 0.016), DSIL (P = 0.004), proximal phalanx (P = 0.001), and PIP joint (P = 0.018), with *Grades 2* and *3* being over-represented and *Grade 0* being under-represented in the limbs with DDFT lesions. There was a difference in the proportions of navicular bone dorsal border grades between limbs with and without DDFT lesions at the level of the proximal phalanx (P = 0.0003). There was a difference in the proportions of navicular bone distal border grades between limbs with and without DDFT lesions at the level of the navicular bone (P = 0.01), and DSIL (P = 0.01) with *Grade 3* being relatively over-represented and *Grade 0* being under-represented in limbs with DDFT lesions. There was a difference in the proportions of navicular bone proximal border grades between limbs with and without DDFT lesions at the level of the DSIL (P = 0.004). There was a difference in the proportions of navicular bone medulla grades between limbs with and without DDFT lesions at the level of the CSL (P = 0.04), and DSIL (P = 0.002), with *Grades 2* and *3* being relatively over-represented and *Grade 0* being under-represented in limbs with DDFT lesions.

When limbs with increased signal intensity, on fat-suppressed images at the origin of the DSIL, or the insertion of the CSL, or in distal border synovial invaginations, or limbs with focal fluid accumulation palmar to the navicular bone were compared with DDFT lesions at different levels, there was only an association between the distal border synovial invaginations and DDFT lesions at the level of the PIP joint (P = 0.003), but at no other levels.

Distal sesamoidean impar ligament: There was a significant difference in the distribution of navicular bone grades between limbs with and without a DSIL lesion for the flexor (P = 0.026), distal (P = 0.0002) and proximal (P = 0.0002) aspects, and for the medulla (P = 0.0009). For all these, a navicular bone *Grade 0* was relatively under-represented and higher grades over-represented in the limbs with DSIL lesions. There was also a significant association for increased signal intensity on fat-suppressed images at the origin of the DSIL (P = 0.026), insertion of the CSL (P = 0.0037) and associated with the fibrocartilage (P = 0.023), with the presence of increased signal intensity being more likely in the limbs with DSIL lesions.

Collateral sesamoidean ligament: There was a significant difference in the distribution of navicular bone grades between limbs, with and without, a CSL lesion for the dorsal ($P = 0.013$), distal ($P = 0.0002$) and proximal ($P = 0.0019$) aspects and for the medulla ($P<0.0001$). For all these, a navicular bone *Grade 0* was relatively under-represented and higher grades over-represented in the limbs with CSL lesions. There was also a significant association for increased signal intensity on fat-suppressed images at the origin of the DSIL ($P = 0.0006$) and insertion of the CSL ($P = 0.0079$), with the presence of increased signal intensity being more likely in the limbs with CSL lesions.

Navicular bursa: There was a significant difference in the distribution of navicular bone grades between limbs with and without a navicular bursa lesion for the flexor ($P = 0.012$), and distal ($P = 0.0045$) aspects, and for the medulla ($P<0.0001$). For all these, a navicular bone *Grade 0* was relatively under-represented and higher grades over-represented in the limbs with navicular bursa lesions. There was a significant association between a navicular bursa lesion and the presence of increased signal intensity in distal border synovial invaginations.

Distal interphalangeal joint: There was a significant difference in the distribution of navicular bone grades between limbs, with and without, DIP joint lesion for the flexor ($P = 0.005$), dorsal ($P = 0.0002$), distal ($P = 0.0037$) and proximal ($P = 0.0042$) aspects and for the medulla ($P = 0.0071$). For all these, a navicular bone *Grade 0* was relatively under-represented and higher grades over-represented in the limbs with DIP joint lesions. There was no association with presence of increased signal intensity on fat-suppressed images at any sites.

Discussion

There was a difference in frequency of core lesions, dorsal abrasions and parasagittal splits at different anatomical locations of the DDFT, thus confirming our hypothesis. Core lesions predominated at the levels of the proximal phalanx and the PIP joint, whereas at the level of the CSL and navicular bone dorsal abrasions and parasagittal splits occurred more frequently. However considering all lesion types, DDFT injury was seen most often at the level of the CSL and navicular bone, followed by the level of the DSIL and insertion, and less frequently at the levels of the PIP joint and proximal phalanx. There was a positive association between lesions of the DSIL, CSL, navicular bursa and DIP joint and lesions of the navicular bone, also confirming the hypothesis.

Lesions of the DDFT were the most common abnormality, but not all lesions would necessarily have been considered likely to contribute to lameness, e.g. a focal split at a single location. Therefore, the prevalence of injury may over-estimate the clinical importance of DDFT pathology. Nonetheless, DDFT injuries either alone or in conjunction with navicular bone pathology are considered important potential causes of lameness, based upon the results of this and other studies (Dyson *et al.* 2003b, 2005; Mair *et al.* 2003). DDFT lesions, comprising sagittal splits, dorsal abrasions and core lesions, at the level of the CSL, navicular bone and DSIL, were most likely to be associated with lesions of the navicular bone involving either the flexor border, spongiosa or distal border. The relationship between dorsal abrasions and sagittal splits of the DDFT and flexor cortex lesions of the navicular bone has been documented (Blunden *et al.* 2006a; Murray *et al.* 2006b) and these degenerative lesions of the DDFT may predispose to lesions of the navicular bone fibrocartilage.

Lesions of the DSIL were more frequent than those of the CSL, but appear to be related. Increased signal intensity in fat-suppressed images in the navicular bone, at the origin of the DSIL, was likely to be seen in association with focal increased signal intensity in the navicular bone at the insertion of the CSL. Lesions of both the DSIL and CSL were seen in association with lesions of the medulla, predominantly linear increased signal intensity in fat-suppressed images extending through the middle third of the bone from the insertion of the CSL to the origin of the DSIL. Such injuries may reflect the lines of stress through the podotrochlear apparatus during extension of the DIP joint. Lesions of both the DSIL and CSL were also seen in association with those of the proximal and distal borders of the bone, such as entheseophtye formation, distal border fragments, and abnormal mineralisation extending from the border into the spongiosa, most commonly distally but also proximally. These abnormalities may be a more chronic response to overstress of the podotrochlear apparatus.

Lesions of the navicular bursa or DIP joint were common and generally comprised distension with abnormal amounts of synovial fluid, with or without synovial proliferation. Lesions of the navicular bursa were likely to occur together with abnormalities of the medulla, flexor or distal borders of the navicular bone. This was the only lesion associated with increased signal intensity in fat-suppressed images in distal border synovial invaginations, except DDFT lesions at the level of the PIP joint. A close association between the navicular bursa and flexor border of the navicular bone is not surprising, given their close anatomical relationship, but the associations between the distal border and medulla were more significant. The interaction with the medulla may be secondary to lesions of the flexor aspect of the bone. Alternatively, stress on the podotrochlear apparatus resulting in injury of the DSIL and increased signal intensity extending through the navicular bone between the attachments of the DSIL and CSL may be associated with distension of the navicular bursa.

There was an association between lesions of the DIP joint and all aspects of the navicular bone, probably reflecting the close anatomical relationship of this joint with both the navicular bone and the DSIL and CSL. The most significant relationship was between the DIP joint and dorsal aspect of the navicular bone reflecting the direct articulation of this surface with the middle and distal phalanges. It has previously been demonstrated that the proximal and distal border angles of the hyaline cartilage of the articular surface of the navicular bone are common sites of the pathology in both horses with chronic palmar foot pain and age-matched control horses (Blunden *et al.* 2006a). Changes in other aspects of the navicular bone may be the result of altered biomechanics because of a change in loading of the DIP joint. Chronic inflammation of the DIP joint has been incriminated as a cause of enlarged synovial invaginations in the distal aspect of the navicular bone (Poulos 1983). Enlarged synovial invaginations may be associated with localised osteonecrosis extending into the cortical and medullary bone (Blunden *et al.* 2006a).

Periarticular osteophytes on the dorsoproximal aspect of the navicular bone were the most common dorsal border lesions. It is currently not known whether such osteophytes reflect primary navicular bone pathology or the navicular bone's role in the DIP joint, although they can be seen in association with other signs of osteoarthritis of the joint.

It is currently unknown what biomechanical factors predispose to the lesions of the podotrochlear apparatus and DDFT described. It has been proposed that reduction in the angle of the distal phalanx within the hoof capsule may be related to increased strain on the DDFT and navicular bone and thus predispose to injury (Eliashar *et al.* 2004; Smith *et al.* 2004). Further information is required about risk factors which might be modifiable to both reduce the prevalence of injury and facilitate recovery after injury.

Manufacturer's address

[1]Analyse-it Software Ltd., Leeds, UK.

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