

Case Report

Use of nuclear scintigraphy and magnetic resonance imaging to diagnose chronic penetrating wounds in the equine foot

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Introduction

Penetrating wounds of the sole and frog in the hoof of the horse are a common and potentially serious injury (Richardson *et al.* 1986; Steckel *et al.* 1989). The exact location of foot penetration has a major prognostic influence. Puncture wounds to the frog (*cuneus ungulae*) and the collateral sulci have a much graver prognosis than similar wounds to the sole (Steckel *et al.* 1989), because the deep digital flexor tendon (DDFT), *bursa podotrochlearis* (navicular bursa), distal sesamoid bone (DSB; navicular bone, *os sesamoidea distalis*), distal sesamoidean impar ligament (DSIL; *lig. sesamoidea distale impar*), distal interphalangeal joint (DIP), distal digital flexor tendon sheath and distal phalanx are at risk.

If an injury is acute and the site of penetration is known, diagnosis is relatively uncomplicated. Radiographic examination combined with the use of a probe inserted into the site of penetration and/or radiographic contrast studies may help to determine the structures involved (Richardson and O'Brien 1985; Lamb 1991; Smith and Schramme 1992). Transcuneal ultrasonography may yield additional information (Busoni and Denoix 2001; Kristoffersen and Thoenes 2003). Endoscopic evaluation of the *bursa podotrochlearis* (Wright *et al.* 1999; Cruz *et al.* 2001) and the proximal palmar recess of the DIP joint (Vacek *et al.* 1992) may facilitate diagnosis and surgical therapy. However, if the injury is chronic or a horse is presented for lameness evaluation with no history of a penetrating wound, diagnosis becomes much more challenging. Scintigraphy (Dyson 2002) and magnetic resonance imaging (MRI) (Tucker and Sande 2001; Dyson *et al.* 2003a; Whitton *et al.* 2003) have the potential to yield further information.

This report describes the clinical, scintigraphic and MRI findings in 2 horses with chronic lameness. These findings were consistent with prior penetrating injuries, although only one

horse had a known history of a minor penetrating wound. The advantages of MRI over other imaging techniques are discussed.

Materials and methods

Two horses with unilateral forelimb lameness and pain localised to the foot were examined at the Centre for Equine Studies of the Animal Health Trust (AHT). One horse (*Case 2*) had a history of a penetrating injury to the frog to a presumed depth of only 1 cm, but the other had no history of trauma. The interval between first detected lameness to referral was approximately 3 months. Both horses had evidence on MRI of a penetrating injury to the foot.

A thorough clinical examination was performed. The lameness was assessed in straight lines on a hard surface and, in *Case 2*, in circles of 10–15 m diameter on both hard and soft surfaces. Lameness was graded on a scale from 0–8 (0 = sound, 2 = mild, 4 = moderate, 6 = severe, 8 = nonweightbearing).

Perineural analgesia of the palmar digital nerves just above the cartilages of the foot was performed with 1.5–2.0 ml mepivacaine hydrochloride USP 2% w/v and lameness was reassessed after 10 mins in straight lines and on a circle.

Lateromedial, dorsoproximal-palmarodistal oblique, palmaroproximal-palmarodistal oblique, weightbearing dorsopalmar and flexed oblique radiographic views of the foot were obtained (Butler *et al.* 2000).

Ultrasonographic examination of the palmar aspect of the pastern region was performed using a 10 MHz linear transducer with and without a stand-off, and at the level of the heel bulbs with a 6.5 MHz convex array transducer. The collateral ligaments of the DIP joint were also assessed.

Nuclear scintigraphic examination of both front feet was performed. Lateral, dorsal and solar views were obtained using vascular, pool and bone phase images (Dyson 2002).

MRI was performed following a procedure described previously (Dyson *et al.* 2003a). Sagittal, dorsal and transverse MR images were obtained using 3-dimensional (3D) T1-weighted spoiled gradient echo (SPGR), 3D T2* gradient echo (GRE) and 2D short inversion recovery (STIR), with a slice thickness of 1.5 mm (SPGR and GRE images) or 4 mm (STIR).

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Case details

History and clinical findings

Case 1

An 8-year-old Thoroughbred-cross gelding was presented with a history of severe left forelimb lameness. The digital pulse amplitudes were increased in both forelimbs. The horse tended to point the left forelimb. A variable degree of left forelimb lameness was noted at walk (grade 1–4/8) and at trot in straight lines on a hard surface (grade 3–4/8). The left forelimb was favoured when turning. Palmar digital nerve blocks abolished the lameness in straight lines.

Case 2

A 14-year-old Thoroughbred gelding had a history of a minor penetrating wound in the apex of the frog in the left front foot and severe lameness. The puncture wound had been treated routinely. The horse became sound, but severe left forelimb lameness recurred when first ridden. A foot cast had been applied.

The right front foot was narrower and more upright than the left. Both front feet were small for the body size of the horse. There were superficial cast rubs on the medial palmar aspect of the left front pastern, and digital pulse amplitudes were increased in both forelimbs.

At walk on a hard surface, the caudal phase of the stride of the left forelimb was short. The horse showed moderate (grade 4/8) left forelimb lameness in straight lines on a hard surface and when lunged on hard and soft surfaces. The left forelimb lameness was substantially improved after palmar digital nerve blocks and mild right forelimb lameness became evident.

Radiography

Case 1 had a round, mineralised opacity close to the lateral tuberosity of the left middle phalanx of unlikely clinical significance. No significant radiological abnormalities were detected in Case 2.

Nuclear scintigraphy

Case 1

There was increased radiopharmaceutical uptake (IRU) in the lateral pool phase image of the left front foot in the region of the DDFT (Dyson *et al.* 2003b), and focal mild IRU in the distal phalanx in the solar bone phase image at the site of the medial insertion of the DDFT.

Case 2

There was intense focal IRU in the region of insertion of the DDFT on the distal phalanx in both pool and bone phase lateral and solar images (Fig 1).

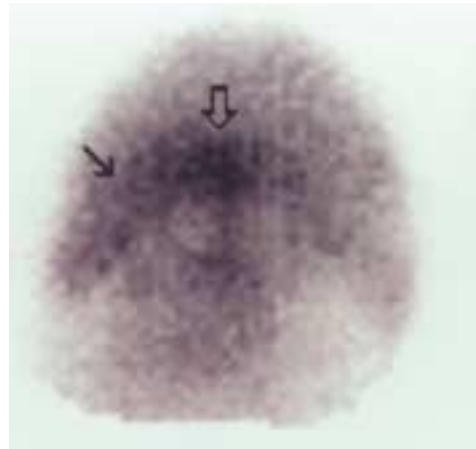


Fig 1: Solar scintigraphic bone phase image of the left front foot of Case 2. Medial is to the left. Intense focal uptake is evident in the region of insertion of the DDFT on the left distal phalanx (large arrow). Diffuse moderate IRU is present in the medial palmar part of the distal phalanx (small arrow).

Ultrasonography

No abnormalities were detected in Case 1. Case 2 had enlargement and central hypoechoic areas in the lateral branch of the superficial digital flexor tendon (SDFT). The lateral abaxial margin was poorly defined.

Magnetic resonance imaging

Case 1

In the left front foot there were 2 focal areas of low signal within the laminae and digital cushion palmarodistal to the DDFT at the level of the DSB (Fig 2). These focal low-signal lesions were seen in SPGR, GRE and STIR sequences. The medial lobe of the DDFT from the level of the DSB to its insertion was markedly enlarged, resulting in close apposition to the DSIL. There was dorsal disruption of the lateral lobe. At the insertion of the DDFT there was increased signal in fat-suppressed images in the medial lobe and the axial part of the lateral lobe (Figs 3, 4). The lesions in the DDFT, digital cushion and laminae were closely related with possible communication and did not respect the borders of the different types of tissue. The DSIL was disrupted and had increased signal, especially medially. The distal phalanx had an irregular cortex at the insertions of the DDFT and DSIL. There was also effusion in the bursa podotrochlearis, DIP joint and digital flexor tendon sheath. The DSB had an increased signal on fat-suppressed images in the distal part of the flexor border and endosteal irregularity medial and lateral to the midline.

Case 2

In the left front foot there were 2 localised areas of decreased signal immediately palmar to the DDFT insertion (Figs 5, 6). There was a linear extension of low signal parallel to the sole through the laminae palmar to the DDFT insertion. These focal



Fig 2: Parasagittal T1-weighted SPGR MR image of Case 1. Two focal areas of low signal are seen in the laminae and digital cushion palmar and distal to the DDFT (open arrows). Enlargement of the distal medial lobe of the DDFT is present (small arrow). The increased signal in the DDFT distal to the DSB is partly due to the 'magic angle' effect. However, there is mottled lower signal near the tendon's insertion due to fluid. The 'magic angle' effect is an artefact, the result of the tendon fibres being orientated at 55° to the static magnetic field.



Fig 3: Parasagittal STIR MR image of Case 1. The same lesion as seen in Figure 2. Enlargement, loss of normal architecture and increased signal are evident in the medial lobe of the DDFT (open arrow). The increased signal in the DDFT is due to fluid accumulation in the tendon, e.g. oedema. There is a focal area of hypointense signal immediately distal to the DDFT.

low-signal lesions were seen in SPGR, GRE and STIR sequences. The solar and cuneal corium was disrupted near to the *apex cuneus*. The DDFT had increased signal and loss of normal architecture from the DSB to its insertion and was inseparable from the DSIL (Figs 5, 7). There was an abnormal signal in T1- and T2-weighted and fat-suppressed images in the palmar aspect of the distal phalanx where the DDFT and DSIL insert, consistent with both fluid and mineralisation. The palmar cortex of the distal phalanx had an irregular outline (Figs 5–7). The lesions in the distal phalanx, DDFT, DSIL and laminae traversed the borders of the tissues. There was effusion in the DIP joint. The lateral branch of the SDF had a more extensive lesion than had been identified ultrasonographically, with



Fig 4: Transverse STIR MR image of Case 1. Medial is to the left. Enlargement, complete loss of normal architecture and a hyperintense signal lesion are evident in the medial lobe of the DDFT (open arrows). There is a focal area of decreased signal in the laminae and digital cushion palmar to the DDFT (small arrow).



Fig 5: Parasagittal T1-weighted SPGR MR image of Case 2. There are focal areas of low signal in the laminae palmar and distal to the DDFT insertion (open arrows). Enlargement and loss of architecture of the distal medial lobe of the DDFT are apparent (small arrow). The increased signal of the DDFT distal to the DSB is partly due to the 'magic angle' effect (see Fig 2), but within this there are areas of lower signal reflecting tendon disruption and fluid. There is diffuse decreased signal in the palmar and proximal aspect of the distal phalanx (double arrow).

hyperintense signal in both T1- and T2-weighted images, occupying a larger proportion of the cross-sectional area and extending further proximodistally.

Conclusions of MRI

The areas of focal hypointense signal seen in all 3 sequences in both horses could have been the result of gas accumulation, mineralisation or deposition of haemosiderin. In both horses the lesions did not respect the borders of the damaged tissues. These findings were interpreted to be lesions following a penetrating injury, with disruption of both tendon and ligament architecture.



Fig 6: Transverse T1-weighted SPGR MR image of Case 2. Medial is to the left. A focal area of decreased signal is present in the DDFT and laminae (arrow). There is an irregular outline of the flexor cortex of the distal phalanx and generalised decreased signal in the mid-body and medial aspect of the distal phalanx.



Fig 7: Parasagittal STIR MR image of Case 2. Enlargement, increased signal and loss of architecture of the DDFT are evident from the level of the DSB to the tendon's insertion on the distal phalanx (open arrow). An area of decreased signal is present in the dorsal aspect of the DDFT at the insertion on the distal phalanx (small arrow). X = increased signal in the cancellous bone in the palmar aspect of the distal phalanx.

Clinical outcome

Based on the severity of the lesions and the chronicity of the lameness, both horses were subjected to euthanasia.

Post mortem examination

A *post mortem* investigation was performed in Case 1. Macroscopic examination revealed a focal haemorrhagic lesion in the medial lobe of the left DDFT and some degenerative changes in the flexor surface of the opposed DSB (**Fig 8a**). There was a triangular area of haemorrhage extending from the frog and digital cushion into the lesion of the medial lobe of the DDFT. New bone formation was evident on the solar aspect of the distal phalanx in the region of insertion of the DDFT. Histological examination confirmed the presence of haemosiderin coincident with the focal areas of hypointense

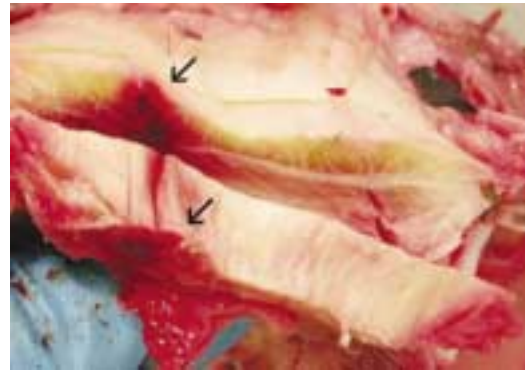


Fig 8a: Gross post mortem photograph from Case 1. The tendon has been cut transversely. The medial lobe of the DDFT is enlarged and has a focal haemorrhagic lesion (arrows).



Fig 8b: Transverse section of the DDFT from Case 1. There is a deep cleft in the dorsal aspect of the tendon filled with fibroplasia, which extended through the tendon into the digital cushion. H&E; Magnification x4.

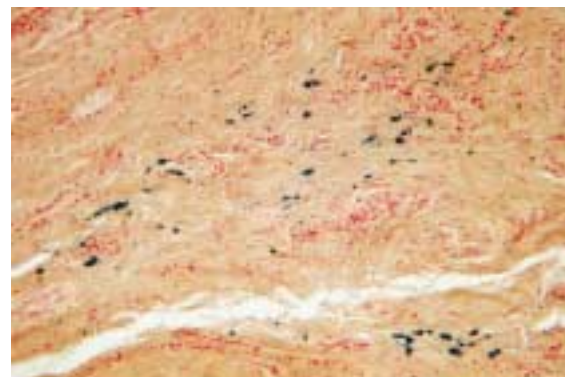


Fig 8c: Section through the digital cushion distal to the deep digital flexor tendon lesion seen in Figure 8b. There is neovascularisation and fibrosis and blue perl positive material consistent with haemosiderin. Magnification x25.

signal seen on MRI (**Figs 8b,c**). There was marked degeneration of regions of the medial lobe of the DDFT, with regions of fibroplasia.

Discussion

Approximately 200 horses with foot pain have been examined using MRI at the AHT between January 2001 and December

2003. One horse had a known deep penetrating injury and very similar findings to these reported here (S. Dyson and R. Murray, unpublished data). The 2 cases described in this paper are the only other horses with evidence of a previous penetrating injury.

None of the clinical findings were specific for a penetrating injury and no draining tract was found; therefore, the diagnostic investigation was complicated. The initial lameness in *Case 2* was probably related to the penetrating injury, and resolved with rest. The owner of *Case 2* clearly underestimated the depth to which the nail had penetrated the frog. The recurrence of the lameness could have been related to the progression of an infectious process (DeBowes and Yovich 1989) or exercise inducing pain from pre-existing injuries.

In both cases, the diagnosis of a penetrating injury was made on the basis of the MRI findings. These included well-defined areas of hypointense signal in the palmar aspect of the DDFT, digital cushion and laminae visible in all 3 image sequences. There was severe disruption of the architecture of the DDFT and DSIL in both horses, and of the flexor cortex of the distal phalanx in *Case 2*.

The DDFT lesions described in this report differed from strain-type injuries to the DDFT. Strain injuries in the DDFT diagnosed with MRI have been described (Dyson *et al.* 2003b; Murray *et al.* 2004). Four types of lesion were seen; core, dorsal border, sagittal plane split and insertional injuries. There was focal or diffuse increased signal in the DDFT in T1- and T2-weighted and STIR images, often associated with enlargement of the DDFT. Insertional lesions were, in some horses, accompanied by irregular endosteal mineralisation and roughening of the flexor cortex of the distal phalanx (Dyson *et al.* 2003b). In the horses described here, the major lesions were in close proximity to the focal areas of hypointense signal and extended through the DDFT and DSIL. The abnormal architecture of the flexor cortex and cancellous bone of the distal phalanx in *Case 2* was not typical of a strain injury. These findings supported a diagnosis of traumatic damage to the DDFT and closely related structures, probably the result of a penetrating injury.

The SDFT injury identified in *Case 2* was considered likely to have been sustained at the same time as the penetrating injury, because the referring veterinary surgeon had noted soft tissue swelling in this area at the time of acute injury. It is notable that the lesion appeared more extensive on MRI than ultrasonographically.

Hypointense signals in soft tissues seen in all 3 image sequences are a manifestation of mineralisation, gas accumulation or deposits of haemosiderin (Bush 2000). In these 2 horses mineralisation seems unlikely, as no changes were detected ultrasonographically or radiographically and their anatomical location was such that the same area should have been visible in a lateromedial radiographic view. Gas accumulation could have been the result of a septic process, but there was no evidence of an active infectious process in the *post mortem* performed in *Case 1*. Septic core lesions in the DDFT in the metacarpal and metatarsal regions have been reported (Kidd *et al.* 2002), but the rarity of these lesions, the

clinical findings, localisation and fast progression of the lesions differ from the chronic cases described here. Haemosiderin is a breakdown product of haemoglobin and its magnetic properties create a hypointense signal in MR images in SPGR, GRE and STIR sequences (Bush 2000). In *Case 1*, the *post mortem* confirmed deposits of haemosiderin in the region of the hypointense signals. Areas of hypointense signal attributed to haemosiderin deposition have previously been described in horses with known penetrating injuries of the foot, but this was not verified by histopathology (Kinns and Mair 2003).

No significant radiographic changes were found. In *Case 2*, an osteitis or septic osteitis of the distal phalanx at the insertion of the DDFT and DSIL was diagnosed with MRI. Septic osteitis of the solar margin of the distal phalanx (Gaughan *et al.* 1989; Cauvin and Munroe 1998) and the DSB (Richardson and O'Brien 1985) has been diagnosed by radiography. Radiographic detection requires a loss of bone density of approximately 40% (Butler *et al.* 2000). The osteitis in *Case 2* was related to the insertion of the DDFT and DSIL, an area that in a lateromedial view is superimposed by the palmar processes and in the dorsoproximal-palmarodistal view by the full thickness of the distal phalanx, so changes in this area are difficult to detect radiographically.

MRI has previously been reported to be more sensitive in detecting changes of bone and with higher resolution than radiography in the horse (Martinelli *et al.* 1996). In man, MRI is considered the best diagnostic imaging technique to diagnose acute osteomyelitis (Restrepo *et al.* 2003). Several studies have shown sensitivity between 82 and 100% and a specificity of 75 to 100% (Schauwecker *et al.* 1990; Restrepo *et al.* 2003).

Arthrography and fistulography are standard methods for investigating penetrating wounds in the foot (Richardson and O'Brien 1985; Lamb 1991; Smith and Schramme 1992), but these methods were not performed in these horses because there were neither draining tracts, nor history of a penetrating injury in *Case 1*. A contrast study of the *bursa podotrochlearis* may have detected an abnormally sized bursa and a dorsally irregular DDFT, but was not indicated based on the clinical findings.

Transcuneal ultrasonography was not performed; it may have had diagnostic value, as both horses had severe tendonopathy in the insertion of the DDFT on the distal phalanx (Busoni and Denoix 2001; Kristoffersen and Thoenfer 2003). However, the major lesions were parasagittal and would not have been visible, nor would the extent of the bony changes.

On scintigraphy, both horses had IRU in the lateral pool phase in the region of the DDFT in the hoof capsule. This correlated well with the MRI findings. False negative scintigraphic results have been reported in horses with MRI evidence of tendonitis of the DDFT (Dyson *et al.* 2003b), but generally in horses with lameness of more than 3 months' duration. In both horses there was focal IRU in the region of the insertion of the DDFT and the DSIL on the distal phalanx in the solar bone phase images. In *Case 1*, this corresponded with an irregular cortex and enthesopathy of the DSIL and DDFT in the medial insertion on the distal phalanx. *Case 2* had

focal intense IRU in the region of insertion of the medial part of the DDFT and DSIL on distal phalanx. The IRU in the distal phalanx was more intense than the findings previously reported in insertional DDFT tendonopathies (Dyson *et al.* 2003b) and adds weight to an alternative aetiopathogenesis. The highly intense focal area of IRU could be the result of a fracture or aseptic or septic osteitis. Bone oedema and mineralisation were seen in MR images as generalised decreased signal intensity in T1-weighted images and mixed signal intensity in T2-weighted images.

If septic osteitis is suspected, other imaging techniques could be considered to gain further information. A radiolabelled white blood cell scan is a scintigraphic method used to detect foci of inflammation. The leucocytes from the patient are usually labelled with ^{99m}technetium (^{99m}Tc), and the radioactive leucocytes migrate to the area of inflammation. This technique detects inflammation and is not specific for an infectious process (Malton 2003).

In LeukoScan¹ a monoclonal antibody is radiolabelled with ^{99m}Tc (Becker *et al.* 1996; Hakki *et al.* 1997). The antibody reacts strongly with antigens on the granulocytes (Becker *et al.* 1996; Hakki *et al.* 1997). The LeukoScan is therefore useful to differentiate inflammatory or infectious processes. A study performed in human subjects (n = 74) with suspected orthopaedic infections compared LeukoScan to a traditional bone scan (^{99m}Tc methylene diphosphonate) and an ¹¹¹indium white blood cell scan. The findings were verified surgically and with histopathology or microbial culture (Becker *et al.* 1996). The sensitivity of the 3 techniques was 93, 85 and 92%, respectively, and the specificity was 89, 75 and 52%, respectively.

In man, it is now recommended that MRI of suspected infectious lesions is also performed using gadolinium enhancement (Ledermann *et al.* 2002). Contrast enhanced images are considered necessary to identify reliably the extent of necrosis and areas of increased vascularity, e.g. an abscess capsule (Ledermann *et al.* 2002). This technique has not been performed routinely at the AHT in horses, but has been used successfully in selected cases (R. Murray and S. Dyson, unpublished data) and would probably have provided additional information. Further studies are required in this area.

Kinns and Mair (2003) described 5 horses with a recent history of a penetrating injury to the foot in which MRI was used to diagnose the extent of the injury. Four horses (80%) returned to previous function with conservative management. Both horses in the present study were subjected to euthanasia because of the poor prognosis for return to full athletic function as competition horses, given the chronicity and extent of the lesions. These authors (S.D. and R.M.) have experience subsequent to submission of this report of 2 horses with known histories of penetrating injuries, that were first examined more than 6 months after injury, had similar lesions and have had persistent lameness. Surgical debridement of puncture wounds into the *bursa podotrochlearis* through the *cuneus unguulae* has been described previously (Richardson *et al.* 1986) and could have been performed to debride the lesions in the DDFT, DSIL, digital cushion and distal phalanx.

The lesions in the DDFT would have required extensive debridement, with the potential complication of DDFT rupture.

Endoscopy of the *bursa podotrochlearis* as a treatment of puncture wounds has been described (Wright *et al.* 1999). The dorsal surface of the DDFT, flexor surface of the DSB and part of the DSIL can be evaluated. Examination may be impeded by inflammation in the DDFT and the *bursa podotrochlearis* (Cruz *et al.* 2001). Ten of 16 horses with mostly acute injuries were reported sound after use of this technique, and only 2 were subjected to euthanasia (Wright *et al.* 1999). Complete debridement of the much more chronic and extensive lesions in this report would, however, have been impossible using this technique.

It is our opinion that the lesions described in this report and their extent could not have been diagnosed without MRI. The intense focal IRU seen in scintigraphy should encourage the diagnostician to perform further investigation of a possible infectious process or a fracture using either MRI or advanced scintigraphic techniques. MRI has potential prognostic value in evaluating acute or chronic penetrating injuries; structures involved can be imaged in detail and therapy can be planned and monitored.

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Manufacturers' addresses

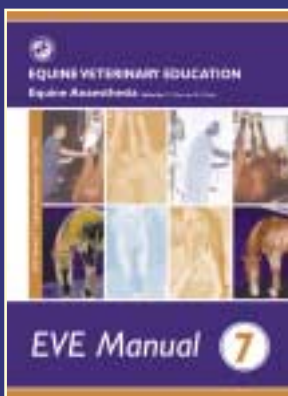
¹Immunomedics Europe, Amsterdam, The Netherlands.

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