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Case Report

Use of magnetic resonance imaging to assess soft tissue damage in the foot following penetrating injury in 3 horses

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Introduction

Magnetic resonance imaging (MRI) uses the magnetic properties of tissues to create a high resolution image, taken in any anatomical plane. The use of MRI in equine diagnostics is still in its infancy, but the technique has great potential in the investigation of many equine diseases, especially diseases of the foot. Conventional imaging modalities, including radiography, diagnostic ultrasonography and nuclear scintigraphy, have significant limitations in assessing the structures within the foot. Magnetic resonance imaging, on the other hand, can provide 3-dimensional images of the entire foot, including both osseous and soft tissue structures. There have been a small number of studies describing the use of MRI in the evaluation of foot pain (Denoix *et al.* 1993; Whitton *et al.* 1998; Widmer *et al.* 2000; Dyson *et al.* 2003); these reports demonstrate the potential for use of the modality in lameness diagnosis. A study of the correlation between MRI images with histological sections confirmed that all of the anatomical structures in the equine digit can be evaluated by MRI (Kleiter *et al.* 1999).

Conventional open and cylindrical human MRI scanners necessitate general anaesthesia in order to scan the horse's leg. A MRI system for use in the standing sedated equine patient has recently become available (Mair *et al.* 2003). It incorporates an open, mobile, 0.2T magnet and a radiofrequency coil that fits around the foot. This system was recently installed at our clinic, and since June 2002 over 300 horses have been scanned in the unit. While both the system and imaging protocols are still under refinement, it has already been particularly beneficial in identifying soft tissue lesions within the foot.

Penetrating foot wounds are a common clinical presentation. Standard investigative procedures of these lesions make use of synoviocentesis and contrast radiography (arthrography, bursography and/or fistulography) to assess synovial (navicular bursa, distal interphalangeal joint and digital tendon sheath) involvement. To date, there has been no universally reliable method of assessing damage to many of the other soft tissue structures within the foot, particularly the deep digital flexor tendon. Diagnostic ultrasonography of the region, performed through the frog and distal pastern, can be helpful but is technically difficult and yields limited information. Previously, those horses that had suffered penetrating wounds which did not recover as predicted may have been assumed to have suffered undiagnosed synovial involvement or tendon/soft tissue damage. Accurate diagnosis and prognosis were therefore hampered by uncertainty.

This case series discusses 3 horses with unresolved lameness following penetrating foot wounds. MRI studies revealed deep digital flexor tendon (DDFT) lesions, presumed to have occurred at the time of the original penetration.

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Case details

History

The 3 horses presented to the Bell Equine Veterinary Clinic between July and September 2002 with a history of penetrating foot wounds. All 3 had ongoing lameness 2 weeks post injury.

Case 1 was a 10-year-old 16 hh Irish x Thoroughbred mare. A 6 inch nail had penetrated the middle third of the lateral sulcus of the frog 6 weeks previously. Plain radiographs taken at the time of injury were unremarkable, and synoviocentesis and radiographic contrast studies of the navicular bursa and distal interphalangeal joint indicated that there was no sepsis or communication between these synovial structures and the wound. Since the injury, the horse had been persistently lame (degree of lameness varying daily from 1/10 to 6/10 lame when trotted in a straight line). Pressure with hoof testers elicited a painful response around the frog and heels. The lameness resolved following an abaxial sesamoid nerve block. A MRI scan was performed 6 weeks after the original injury.

Case 2 was a 7-year-old Thoroughbred gelding with a 6/10 right forelimb lameness of 1–2 weeks' duration following a suspected penetrating wound. A deep, foul-smelling puncture was found in the middle third of the medial sulcus and pressure from hoof testers resulted in a painful response

Fig 1: Radiograph of Case 3 *showing probe in penetrating tract.*

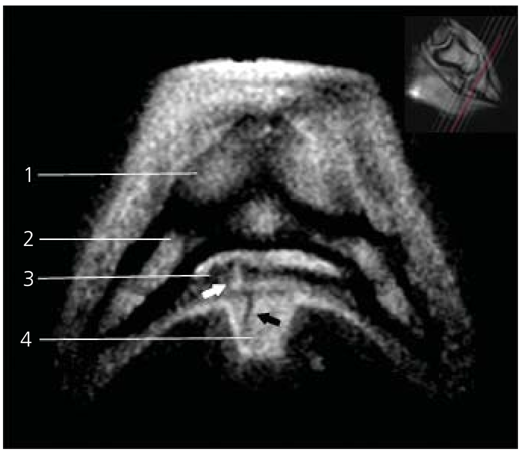

Fig 2: T1-weighted transverse oblique image of* Case 1 *taken proximal to the deep digital flexor tendon (DDFT) insertion. A lesion is visible as a hyperintense line within the lateral lobe of the DDFT (white arrow). There is also a tract of reduced intensity (black arrow) present within the cuneal part of the digital cushion, presumed to relate to the original penetration. 1 = Distal end of middle phalanx; 2 = distal phalanx; 3 = DDFT; 4 = cuneal part of digital cushion.

on the sole adjacent to the wound. Radiographs taken with a probe in the puncture demonstrated a deep penetrating wound that extended to within 5 mm of the flexor surface of the navicular bone. A radiographic contrast bursogram of the navicular bursa showed no communication with the wound. Synoviocentesis of the distal interphalangeal joint and navicular bursa yielded normal fluid. A MRI study was performed 2 weeks after the original injury.

Case 3 was a 6-year-old 15.1 hh Morgan x Thoroughbred gelding who became acutely lame while out hacking. On examination 24 h later, a nail tract was found in the proximal third of the medial frog sulcus. Pressure from hoof testers resulted in a painful response at this point. Radiography taken with a probe in the tract showed that it approached but did not touch the distal third of the flexor surface of the navicular bone (**Fig 1**). Synoviocentesis of the distal interphalangeal joint, navicular bursa and digital sheath, and a contrast radiographic study, suggested that there was no synovial involvement. MRI scans were performed 48 h after the original injury, and again at 2 weeks.

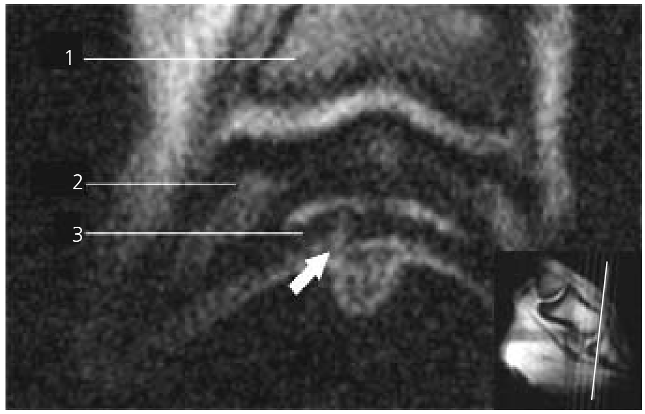

Fig 3: T2*-weighted transverse oblique image of* Case 1 *taken proximal to the deep digital flexor tendon (DDFT) insertion. A vertical hyperintensity (arrow) is seen in the lateral lobe of the DDFT, confirming that seen in Figure 2. 1 = Middle phalanx; 2 = distal phalanx; 3 = DDFT.

MRI was performed in the standing, sedated horse, using a dedicated equine limb MRI scanner[1] (Mair *et al.* 2005). T1- and T2*-weighted images were acquired in sagittal and transverse oblique planes.

MRI results

Case 1 had a lesion in the lateral lobe of the deep digital flexor tendon distal to the navicular bone. Transverse oblique T1-weighted images (**Fig 2**) of this area showed a narrow vertical hyperintensity bisecting the lateral lobe of the DDFT. Sagittal T1 images also showed thickening of the DDFT proximal to its insertion onto the distal phalanx. Some roughening was present on the dorsal border of the DDFT in this area. The findings were confirmed with T2*-weighted images (**Fig 3**), in which the lesion was also evident as a line of hyperintensity. A loss of signal was also seen in a line penetrating the frog and exiting the cuneal digital cushion just medial to the DDFT lesion. This was presumed to correspond to the site and tract of the original penetrating injury.

Case 2 was found to have sustained a lesion in the centre of the medial lobe of the DDFT immediately proximal to its insertion. This was apparent as a line of increased intensity on both T1 (**Fig 4**) and T2* transverse oblique images. The distal sesamoidean impar ligament appeared thickened medially with a slight focal increase in intensity corresponding to the position of the lesion in the DDFT. There was a slight effusion evident in the distal interphalangeal joint.

Case 3 was scanned at 48 h and 2 weeks post injury. At 48 h, there were marked areas of reduced intensity associated with the site of the original penetration (**Figs 5** and **6**). The DDFT was partially obscured by an area of low signal on both T1 and T2* images, indicating that it was not fluid-filled. The contrast medium used in the initial work-up was evident as a

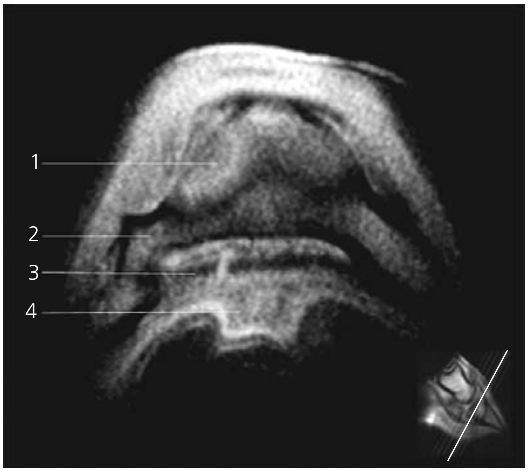

Fig 4: T1-weighted transverse oblique image of Case 2 *taken proximal to the deep digital flexor tendon (DDFT) insertion. A clear vertical hyperintensity is seen bisecting the medial lobe of the DDFT. 1 = Middle phalanx; 2 = distal phalanx; 3 = DDFT; 4 = cuneal part of digital cushion.*

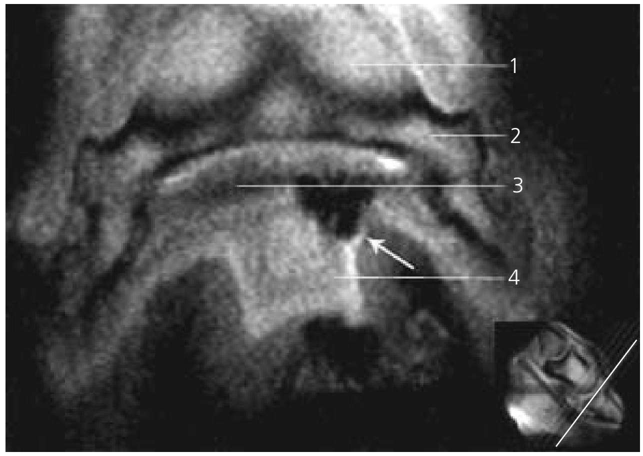

Fig 6. T1-weighted transverse oblique image of Case 3 *taken distal to the navicular bone 2 days post injury. The area of hypointensity seen on Figure 5 is evident here overlying the medial deep digital flexor tendon. 1 = Middle phalanx; 2 = distal phalanx; 3 = deep digital flexor tendon; 4 = cuneal part of digital cushion.*

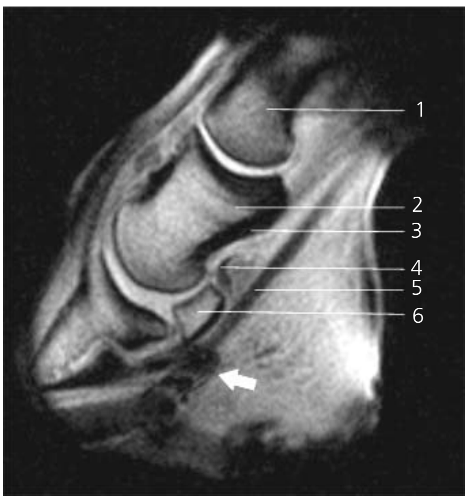

Fig 5: T1-weighted sagittal image of Case 3 *of the foot 5 mm medial to midline taken 2 days post injury. A large area of hypointensity (white arrow) crosses the digital cushion and the medial DDFT. 1 = Proximal phalanx; 2 = medullary cavity/trabecular bone of middle phalanx; 3 = cortical bone of middle phalanx; 4 = collateral sesamoidean ligament; 5 = deep digital flexor tendon; 6 = medullary cavity of navicular bone.*

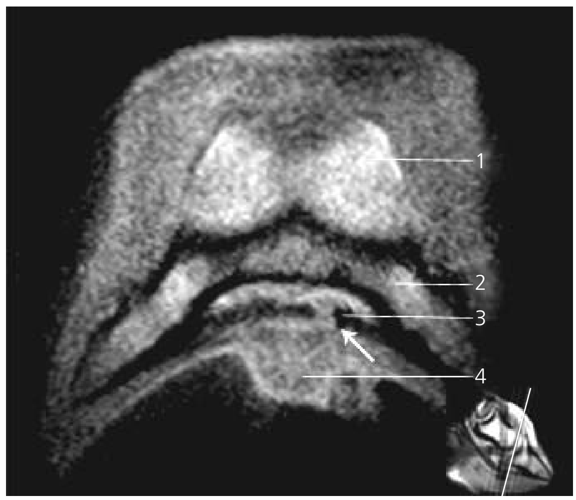

Fig 7: T1-weighted transverse oblique image of Case 3 *taken distal to the navicular bone 2 weeks post injury. A thick vertical hyperintensity is seen in the medial lobe of the deep digital flexor tendon (white arrow). There is soft tissue proliferation medial to the frog. 1 = Middle phalanx; 2 = distal phalanx; 3 = deep digital flexor tendon; 4 = cuneal part of digital cushion.*

narrow line of increased intensity on T1 images, 'lining' the distal part of the penetrating tract. This contrast medium had previously been shown to produce a high signal intensity on both T1- and T2*-weighted sequences. It was not evident in association with the tendon.

At 2 weeks post injury, the horse was found to have a DDFT lesion in the medial lobe, just proximal to its insertion and extending proximally to the level of the distal third of the navicular bone. The lesion appeared on T1 images as a hyperintense area bisecting the medial lobe of the DDFT (**Fig 7**). It was also of increased intensity on T2* images, suggesting a fluid component to the lesion. Part of the tract was still apparent, including an area of reduced intensity palmar to the lesion.

Follow-up

Case 1 was box-rested for 5 months and paddock-rested for a further 3 months. After this period the mare was examined and found to be sound. MRI was performed 8 months after the original scan. The lesion was no longer present and the mare was brought slowly back in to work.

Case 2 was paddock-rested for 6 months, then examined at 3 months and found to be 2/10 lame at trot in a straight line. After 6 months, the owners elected to begin walking exercise in hand. At 11 months after the original scan, the horse was examined and found to be sound. A repeat MRI scan at that time showed that the tendon lesion was still evident as a narrow hyperintense line.

Case 3 was box-rested for 3 months. The horse was reportedly sound after 8 weeks and the owners elected to turn the animal out in a paddock at 12 weeks. Re-examination after 5 months revealed the horse to be clinically sound. An MRI scan at the time showed no evidence of any lesion. The horse was was then brought back in to work gradually, and remained sound.

Discussion

Penetrating wounds of the foot are a common occurrence in equine practice. Deep penetrations of the frog region can result in damage and/or infection of a number of vital structures, which may be career- or life-threatening (Steckel *et al.* 1989). The approximate depth of a perpendicular penetration that can affect vital structures is as little as 1 cm for the sole and 1.5 cm for the frog (Stashak 2002). Early identification of the involvement of a vital structure and prompt treatment are essential for a successful outcome (Richardson *et al.* 1986a,b; Honnas *et al.* 1988; DeBowes and Yovich 1989; Stashak 1998; Richardson 1999). Foot wounds can be classified according to their depth and location (Richardson *et al.* 1986a). *Type II* wounds penetrate the corium deep to the frog, and may result in septic deep digital flexor tendonitis, septic navicular bursitis, distal interphalangeal joint septic arthritis, septic tenosynovitis of the digital sheath, abscess of the digital cushion, septic osteitis of the distal phalanx or navicular bone, or fractures of the distal phalanx. Plain radiography, radiography with a sterile metal probe placed in the tract, and contrast radiography are commonly used techniques to assess the direction and depth of the penetration, and to investigate the involvement of vital structures (primarily the synovial structures) (Smith and Schramme 1992; Stashak 2002). Although it may be possible to predict involvement of the DDFT by assessing the distance between the end of the metal probe and the flexor cortex of the navicular bone, these techniques cannot conclusively identify DDFT damage distal to the level of the digital sheath. Septic tendinitis of the DDFT is one of the potential reasons why horses with such penetrating wounds may fail to return to soundness, even after appropriate treatment of synovial sepsis (Richardson *et al.* 1986a,b; Steckel *et al.* 1989; Stashak 2002). The accurate identification of DDFT lesions using MRI in such cases may help in dictating the most appropriate treatment (e.g. medical therapy, surgical therapy and therapeutic shoeing) and determining the prognosis.

Standing equine MRI is likely to become a valuable tool in assessing lesions within the foot (Mair *et al.* 2005). The advantages gained from avoiding the risks and cost of a general anaesthetic procedure that is required when conventional human MRI scanners are used can outweigh the limitations of resolution with the less powerful magnet. Patients with penetrating foot lesions are ideal candidates for early survey scanning with MRI. The modality can provide excellent soft tissue contrast. T1 images give good anatomical definition, while T2-weighted images have proved to be more sensitive to changes in the composition of soft tissue structures such as tendons (Dyson *et al.* 2003). Movement does not provide a major problem in standing MRI of the foot. Although considerable 'sway' is occasionally observed in the limb, the foot remains static, and movement correction features are not usually required.

It should be possible to identify involvement of synovial structures in penetrating lesions of the foot more reliably with MRI than with contrast radiography. The tract of the penetrating wound was identified in all 3 of the cases described here, even though the images were obtained several weeks after the injury. Synovial proliferation and fluid distension of infected cavities would be predicted. Although in *Cases 2* and *3* the area of low signal appeared to show full thickness penetration of the DDFT, there was no synovial sepsis. This cannot be explained by MRI findings alone. It appears that the synovial lining of the navicular bursa and the distal interphalangeal joint were not penetrated by the injuries, and therefore no sepsis occurred. The use of the MRI contrast medium gadolinium might be considered when evaluating such injuries in future cases.

As demonstrated in these 3 cases, where tendon lesions are associated with a penetrating wound, standing MRI can be used to make this diagnosis. Treatment protocols and prognoses can then be adjusted accordingly. Deep digital flexor tendon lesions within the foot have not been reliably diagnosed in the live horse prior to the advent of MRI scanning. The DDFT within the foot can be imaged using diagnostic ultrasonography performed via the sagittal midline of the frog or the distal pastern (Sage and Turner 2000; Busoni and Denoix 2001), but these techniques often fail to identify subtle tendon lesions because it is not possible to position the transducer perpendicular to the tendon fibres. Lesions occurring at the level of the navicular bone will be seen by ultrasonography only if they lie in the midline; lesions that are confined to either the medial or lateral lobe of the DDFT (which includes the majority of such tendon lesions) will not be imaged. Consequently, it is impossible to attain an accurate diagnosis or prognosis. Treatment protocols generally include box-rest and the fitting of a raised heel, but a guarded prognosis must be given for return to soundness.

The areas of hypointensity seen in association with the penetrating tract can be explained in one of several ways. Substances appearing to have very low signal intensity on both T1- and T2-weighted images include mineralisation, haemosiderin, oxyhaemoglobin and air. Oxyhaemoglobin would only be present in the acute stages of injury, while air and haemosiderin could persist for several weeks, and mineralisation is likely to be evident as a chronic change months after the injury.

In cases associated with a penetrating injury, the possibility of septic tendinitis should be considered and surgical debridement of the infected tissue may be indicated (Richardson *et al.* 1986b; Turner 1990). At the present time, there is insufficient information available to know whether

MRI could be used to distinguish septic from aseptic tendinitis in horses. In the cases described here, treatment included superficial debridement of the wound and systemic antimicrobial therapy; no surgical debridement of the tendon lesions was attempted. Although it is uncertain whether the tendon lesions in these horses were septic, long-term improvement occurred without surgical interference.

MRI is a very new diagnostic tool in equine medicine and the interpretation of images, particularly on lower resolution standing systems, requires care. It has been shown previously that early tendon lesions exhibit a very high intensity signal on T2-weighted MRI scans, but that this increased signal declines with early fibrogenesis, even when the area remains hypoechogenic on ultrasonography (Crass *et al.* 1992). Repeat scans to assess healing should therefore be taken several months post injury rather than in the early stages. Greater sensitivity to tendon damage can be achieved with very short TE times (Schick *et al.* 1995; Whitton *et al.* 1998) and modification of the sequencing may therefore prove helpful in the evaluation of such cases. The use of thinner slices also improves the visualisation of small lesions and improves fine detail (Whitton *et al.* 1998). These were unavailable at the time of examination of these cases.

Although not available at the time for the 3 cases reported here, the use of STIR MRI sequences should also prove beneficial in evaluating potential damage to the bony structures, including the distal phalanx and navicular bone. Osseous radiographic changes are frequently not evident for 1–2 weeks post injury (Turner 1990), whereas MRI changes are likely to be identifiable immediately. In man, MRI is currently considered the most sensitive technique for detecting bone pathology, such as osteonecrosis, osteomyelitis and trauma, including bone contusion (Jiang *et al.* 1999). MRI is also proving to be sensitive in detecting bone pathology in horses (Schneider 2002; Dyson *et al.* 2003).

MRI in the standing, sedated horse has the potential to be a useful tool for assessing both soft tissue and bony structures within the foot. Movement correction features will also allow more proximal structures to be assessed. At this stage, it is ideal for the study of potentially complicated penetrating wounds of the foot. DDFT lesions associated with these wounds may have remained undiagnosed before the advent of MRI. The standing system provides a valuable alternative to the use of more powerful magnets in the anaesthetised patient in selected cases.

Manufacturer's address

[1]Hallmarq Veterinary Imaging, Guildford, Surrey, UK.

References

Busoni, V. and Denoix, J.-M. (2001) Ultrasonography of the podotrochlear apparatus in the horse using a transcuneal approach: technique and reference images. *Vet. Radiol. Ultrasound* **42**, 534-540.

Crass, J.R., Genovese, R.L., Render, J.A. and Bellon, E.M. (1992) Magnetic resonance, ultrasound and histopathologic correlation of acute and healing equine tendon injuries. *Vet. Radiol. Ultrasound* **33**, 206-216.

DeBowes, R.M. and Yovich, J.V. (1989) Penetrating wounds, abscesses, gravel, and bruising of the equine foot. *Vet. Clin. N. Am.: Equine Pract.* **5**, 179-194.

Denoix, J.-M., Crevier, N., Roger, B. and Lebas, J. (1993) Magnetic resonance imaging of the equine foot. *Vet. Radiol. Ultrasound* **34**, 405-411.

Dyson, S., Murray, R., Schramme, M. and Branch, M. (2003) Magnetic resonance imaging of the equine foot: 15 horses. *Equine vet. J.* **35**, 18-26.

Honnas, C.M., Meagher, D.M. and Lindford, R.L. (1988) Surgical management of difficult foot problems in the horse: current concepts. *Proc. Am. Ass. equine Practnrs.* **34**, 249.

Jiang, Y., Peterfly, C., Zhao, J., White, D., Lynch, J. and Genant, H. (1999) Magnetic resonance imaging in osteoarthritis. In: *Osteoarthritis, Clinical and Experimental Aspects*, Eds: J.Y. Reginster, J.P. Pellitier, J. Martel-Pellitier and Y. Henrotin, Springer-Verlag, New York. pp 268-295.

Kleiter, M., Kneissl, S., Stanek, C., Mayrhoffer, E., Baulain, U. and Deegen, E. (1999) Evaluation of magnetic imaging techniques in the equine digit. *Vet. Radiol. Ultrasound* **40**, 15-22.

Mair, T.S., Kinns, J., Jones, R.D. and Bolas, N.M. (2005) Magnetic resonance imaging of the distal limb of the standing horse. *Equine vet. Educ.* **17**, 74-78.

Richardson, G.L. (1999) Surgical management of penetrating wounds to the equine foot. *Proc. Am. Ass. equine Practnrs.* **45**, 198-189.

Richardson, G.L., Pascoe, J.R. and Meagher, D. (1986a) Puncture wounds of the foot in horses: Diagnosis and treatment. *Comp. cont. Educ. pract. Vet*. **8**, S379-S387.

Richardson, G.L., O'Brien, T.R., Pascoe, J.R. and Meagher, D.M. (1986b) Puncture wounds of the navicular bursa in 38 horses: a retrospective study. *Vet. Surg.* **15**, 156-160.

Sage, A. and Turner, A. (2000) Ultrasonography in horses with palmar foot pain: 13 cases. *Proc. Am. Ass. equine Practnrs.* **46**, 380-381.

Schick, F., Dammann, F., Lutz, O. and Claussen, C. (1995) Adapted techniques for clinical MRI imaging of tendons. *Mag. Res. Mat. Phys. Biol. Med*. **3**, 103-107.

Schneider, R. (2002) Magnetic resonance imaging (MRI): what have we learned? In: *Proceedings of the 12th Annual Veterinary Symposium of the American College of Veterinary Surgeons*, American College of Veterinary Surgeons, San Diego. pp 75-76.

Smith, R.K.W and Schramme, M.C. (1992) The use of contrast agents in the diagnosis of penetrating wounds of the foot in 5 cases. *Equine vet. Educ.* **4**, 177-182.

Stashak, T.S. (1998) Avulsion and penetrating injuries of the foot. In: *Proceedings of the 20th Bain-Fallon Memorial Lecture*, Queensland. pp 245-256.

Stashak, T.S. (Ed) (2002) Penetrating wounds of the foot. In: *Adams' Lameness in Horses*, 5th edn., Lippincott, Williams and Wilkins, Philadelphia. pp 703-710.

Steckel, R.R., Fessler, J.F. and Huston, L.C. (1989) Deep puncture wounds of the equine hoof: a review of 50 cases. *Proc. Am. Ass. equine Practnrs.* **35**, 67.

Turner, T.A. (1990) Abscesses and punctures of the foot. In: *Current Practice of Equine Surgery*, Eds: N.A. White and J.N. Moore, J.B. Lippincott, Philadelphia. pp 397-401.

Whitton, C., Buckley, C., Donovan, T., Wales, A. and Dennis, R. (1998) The diagnosis of lameness associated with distal limb pathology in a horse: a comparison of radiography, computed tomography and magnetic resonance imaging. *Vet. J.* **155**, 223-229.

Widmer, A., Buckwater, K., Fessler, J., Hill, M., van Sickle, D. and Ivancevich, S. (2000) Use of radiography, computed tomography and magnetic resonance imaging for evaluation of navicular syndrome in the horse. *Vet. Radiol. Ultrasound* **41**, 108-116.