Review Article

Injuries associated with the cartilages of the foot

S. Dyson* and A. Nagy

Centre for Equine Studies, Animal Health Trust, Lanwades Park, Kentford, Newmarket, Suffolk CB8 7UU, UK.

Keywords: horse; ossification; cartilage; foot; injury

Summary

There is a growing body of evidence that uniaxial or biaxial ossification of the cartilages of the foot should not be discounted as irrelevant in a lame horse, especially if extensive. Potential causes of pain and lameness include primary injury of an ossified cartilage and/or the ipsilateral aspect of the distal phalanx, injury of the chondrocoronal or chondrosesamoidean ligaments and desmopathy of the collateral ligaments of the distal interphalangeal joint.

Introduction

Ossification of the cartilages of the foot has long been recognised and historically was considered of clinical importance especially in draught breeds (O'Connor 1944) but in more recent years the clinical significance of injuries of the cartilages of the foot has largely gone unrecognised. However, there is a growing body of evidence to suggest that the ossified cartilages of the foot can sustain primary injury (Ruohoniemi *et al*. 2004; Dakin *et al*. 2006; Dyson 2008; Dyson and Murray 2010) or be associated with other injuries in the foot, notably the distal phalanx and the collateral ligaments (CLs) of the distal interphalangeal (DIP) joint (Dyson and Murray 2007a,b; Dyson 2008; Mair and Sherlock 2008; Dyson *et al*. 2010). The objectives of this paper are to review: 1) Functional anatomy of the cartilages of the foot, 2) The normal radiological, scintigraphic and magnetic resonance imaging (MRI) appearances of the cartilages of the foot and 3) Injuries of the cartilages of the foot and closely related anatomical structures.

Functional anatomy of the cartilages of the foot

The cartilages of the foot, otherwise known as the ungular or collateral cartilages, are C- to L-shaped structures attached to the distal phalanx and extend proximally on the medial and lateral aspects of the foot to just proximal to the coronary band. The cartilages of the foot extend in a dorsopalmar direction from dorsal to the dorsal aspect of the middle phalanx towards the palmar aspect of the distal phalanx and sometimes beyond. They have variably sized axial extensions that are intimately associated with the digital cushion (Bowker 2003). Sidebone refers to ossification of the cartilages of the foot that usually starts at the base of the cartilage, at its attachment to the distal phalanx and progresses proximally. Less commonly, separate centres of ossification (SCsO) may develop that extend proximally or distally. If ossification originating from a separate centre occurs concurrently with ossification from the base of the cartilage, a radiolucent line may exist between the 2 sites and may persist throughout life. Similarly, there may be an unossified junction between ossification of the base of a cartilage and the distal phalanx. In some horses, there are discrete SCsO proximally, well separated from ossification further distally.

The cartilages of the foot are connected to surrounding structures, such as the digital cushion, proximal, middle and distal phalanges and navicular bone by small ligaments, including the chondroungular, chondrocoronal, chondrocompedal and chondrosesamoidean ligaments. There is also a close anatomical relationship between the cartilages of the foot and the CLs of the DIP joint and a fibrocartilaginous ligament extending to the deep digital flexor tendon.

The cartilages of the foot are thought to reduce concussion to structures within the foot (Bowker *et al*. 1998) and to assist blood flow by compression of the venous plexuses of the foot during loading. Both functions are assisted by multiple vascular foramina that contain large central veins joined to a network of microvessels, termed venovenous anastomoses, which may be critical to energy dissipation during impact of the hoof with the ground. As the foot contacts the ground, blood is forced through the microvasculature, which supplies resistance to flow, allowing energy to be dissipated through the cartilages of the foot and fluid, rather than through the ligamentous

*Corresponding author email: sue.dyson@aht.org.uk

and bony structures within the foot. A negative pressure within the palmar aspect of the foot aids rapid refilling of the microvasculature for the next loading phase. In feet with thick cartilages of the foot, enclosing more microvessels within the vascular channels, more energy is dissipated on ground contact compared with feet with thin cartilages of the foot.

Horses with a low height-to-bodyweight ratio often move with a pronounced upward and downward action, landing heavily on their feet with each loading phase of the stride. This produces large concussive forces on the feet, from which the energy must be dissipated. Continuous energy dissipation through the cartilages of the foot may cause a change in the structure and subsequent ossification of the cartilages of the foot. Alternatively, ossification of the cartilages of the foot may be an evolutionary adaptation in these types of horses in response to their gait.

The distal aspects of the cartilages of the foot contain more venovenous anastomoses than the proximal parts. The greater abundance of venovenous anastomoses at the base of the cartilages may explain why ossification starts distally more often than from a SCO, because this is where most of the energy is first concentrated at the start of dissipation. A recent study has indicated that there is greater radiopharmaceutical uptake (RU) at the base of the cartilages of the foot than further proximally, indicating greater bone modelling (Nagy *et al*. 2007). The general symmetry of ossification between left and right feet (Ruohoniemi *et al*. 1993; Down *et al*. 2007) suggests a hereditary predisposition, supported by the estimated high heritability in Finnhorses (Ruohoniemi *et al*. 2003).

Diagnostic imaging of the cartilages of the foot

Radiography and radiology of the cartilages of the foot

A combination of 5 radiographic projections is recommended for accurate radiological assessment of the cartilages of the foot: weightbearing dorsopalmar (DPa), lateromedial (LM), dorsoproximal-palmarodistal oblique (DPr-PaDiO) and flexed dorsolateral-palmaromedial oblique (DL-PaMO) and dorsomedial-palmarolateral oblique views (Butler *et al*. 2008). A method of grading the degree of ossification of the cartilages of the foot (*grades 0–5*) from weightbearing DPa radiographic images was proposed by Ruohoniemi *et al*. (1993) and recently modified (Dyson *et al*. 2010) (**Table 1** and **Fig 1**). This takes into account the dorsoproximal extent of ossification, but does not assess the extent of dorsopalmar ossification, which is also variable (**Fig 2**). The term 'possibly significant ossification' was proposed as being suggestive of clinical significance, defined as *grades 3* plus a SCO, *4* and *5* (Ruohoniemi *et al*. 1993).

TABLE 1: Radiological grades of ossification of the cartilages of the foot, based upon weightbearing dorsopalmar radiographic images (from Dyson *et al*. 2010)

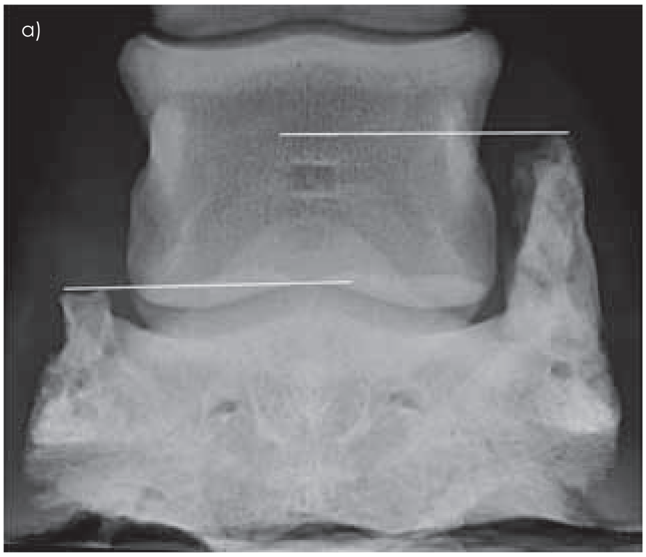
Grade	Radiological criteria
0	No ossification
1	Ossification up to the level of the medial or lateral margins of the distal interphalangeal joint
2	Ossification up to the level of the central (axial) aspect of the distal interphalangeal joint
3	Ossification up to the most proximal aspect of the navicular bone (excluding proximal entheseophytes)
4	Ossification up to the mid point of the middle phalanx (based on the most proximal aspect of the joint surface)
5	Ossification proximal to the mid point of the middle phalanx

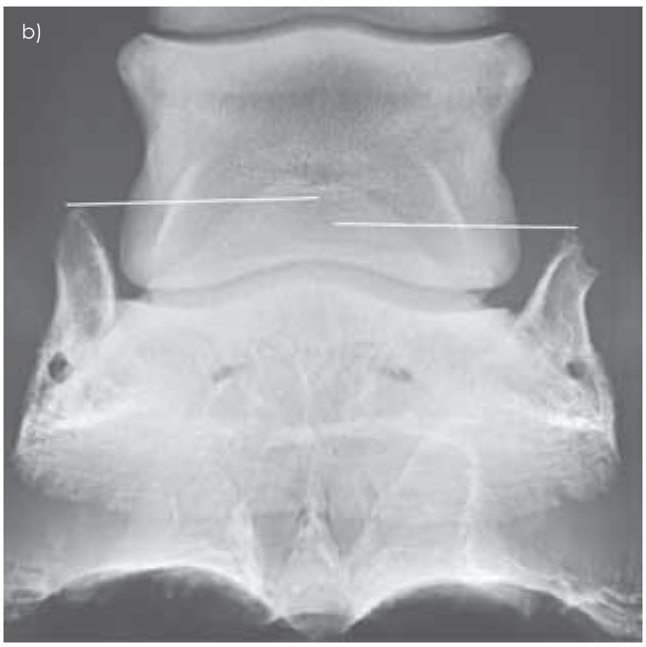
Ossified cartilages usually have uniform radiopacity and the cortices are uniform in thickness and have a smooth outline. The junction between 2 ossification centres is usually smoothly demarcated. In DPa and oblique radiographic views the width of the SCsO proximal and distal to the junction is usually similar. Modelling at the junction between ossification centres probably reflects previous trauma to an unstable union, but can be difficult to differentiate from a fracture. Ascribing clinical significance can be challenging without nuclear scintigraphy and/or MRI.

Prevalence of ossification

Mild ossification (*grades 1* and *2*) of the cartilages of the foot is widespread. Moderate or extensive (*grades 4* and *5*) ossification of the cartilages of the foot is common in the front feet of heavy horses, but is less common in ponies, Warmbloods and Thoroughbreds. Approximately 80% of Finnhorses in Finland (Ruohoniemi *et al*. 1993, 1997) and draught horses in Belgium (Verschooten *et al*. 1996) have radiological evidence of ossification of the cartilages of the foot; there is also a high prevalence in Norwegian coldblooded horses in Norway (Holm *et al*. 2000). In a referral population of horses at the Animal Health Trust in Great Britain, high ossification grades were overrepresented in large native ponies (e.g. Dales, Highland, Fell and Connemara breeds) and cob-types of horses, compared with other breeds (Irish Draught, Crossbred, Thoroughbred, Thoroughbred cross, Warmblood and pony) (Down *et al*. 2007). Heavy horses and horses with low height-to-bodyweight ratios had a greater degree of ossification than others. In horses examined bilaterally, left-right symmetry of ossification was present.

Among Finnhorses (Ruohoniemi 1997) and Brazilian jumping horses of unspecified breed (Silva and Vulcano 2002) ossification was more common and extensive in mares compared with male horses, but no gender predilection was seen in the British study of mixed breeds (Down *et al*. 2007). There was no association with age





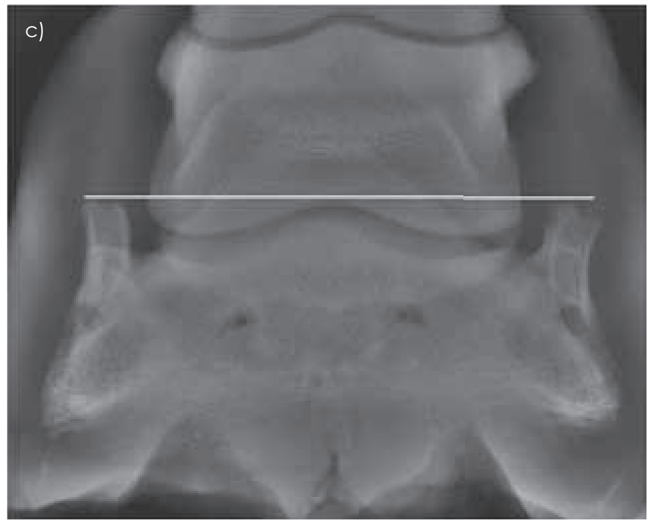


Fig 1: a) Dorsopalmar radiographic image of a foot. Lateral is to the right. There is markedly asymmetrical ossification of the cartilages of the foot,* grade 2 *medially and* grade 5 *laterally. Note also a reverse L-shaped radiolucent line in the lateral ossified cartilage which probably reflects the junction between separate centres of ossification. Despite the lack of statistical association between markedly asymmetric ossification of the cartilages of the foot and distal phalanx injury in a recent study (Dyson* et al. *2010), this 7-year-old Irish sports horse had lameness associated with osseous trauma of the lateral aspect of the distal phalanx. b) Dorsopalmar radiographic image of a foot to show biaxial* grade 4 *ossification of the cartilages of the foot (ossification extending to the distal half of the middle phalanx). Medial is to the left. c) Dorsopalmar radiographic image of a foot to show biaxial* grade 3 *ossification of the cartilages of the foot (ossification up to the most proximal aspect of the navicular bone, excluding entheseophytes). Medial is to the left.

(Ruohoniemi *et al*. 1997; Down *et al*. 2007). Lateral ossification is frequently more extensive than medial (Ruohoniemi *et al*. 1993, 1997, 2003; Down *et al*. 2007; Mair and Sherlock 2008), although heritability of ossification in Finnhorses is similar for both lateral and medial cartilages (Ruohoniemi *et al*. 2003). Marked mediolateral asymmetry of ossification of the cartilages of the foot is unusual (Ruohoniemi *et al*. 2003; Down *et al*. 2007).

Normal magnetic resonance imaging appearance of the cartilages of the foot

The cartilages of the foot are variably curved proximodistally, being convex abaxially (**Fig 3a**) (Dyson and Murray 2010). They are generally similar in mediolateral thickness from proximal to distal and have slightly heterogeneous intermediate signal intensity in T1 and T2 weighted magnetic resonance (MR) images and uniform low signal intensity in fat suppressed images. At the level of the middle phalanx there are frequently large blood vessels axial to the proximal aspect of the cartilage (the deep ungular plexus) (**Figs 3a–c**). The number of detectable vessels within the cartilages varies among horses. In horses with ossification, the cartilages of the foot are usually cartilaginous at their most dorsal extent and the ossification extends palmar from the dorsal aspect of middle phalanx or, more commonly, from the navicular bone palmad (**Fig 3d**). Ossified cartilages usually have smooth cortices of even thickness, which have low signal intensity in all image sequences. In T1 and T2 weighted MR images the trabecular bone of ossified cartilages has moderately high signal intensity. In some horses there are one or more SCsO proximally, occurring most often at the junction between the proximal and distal halves of the

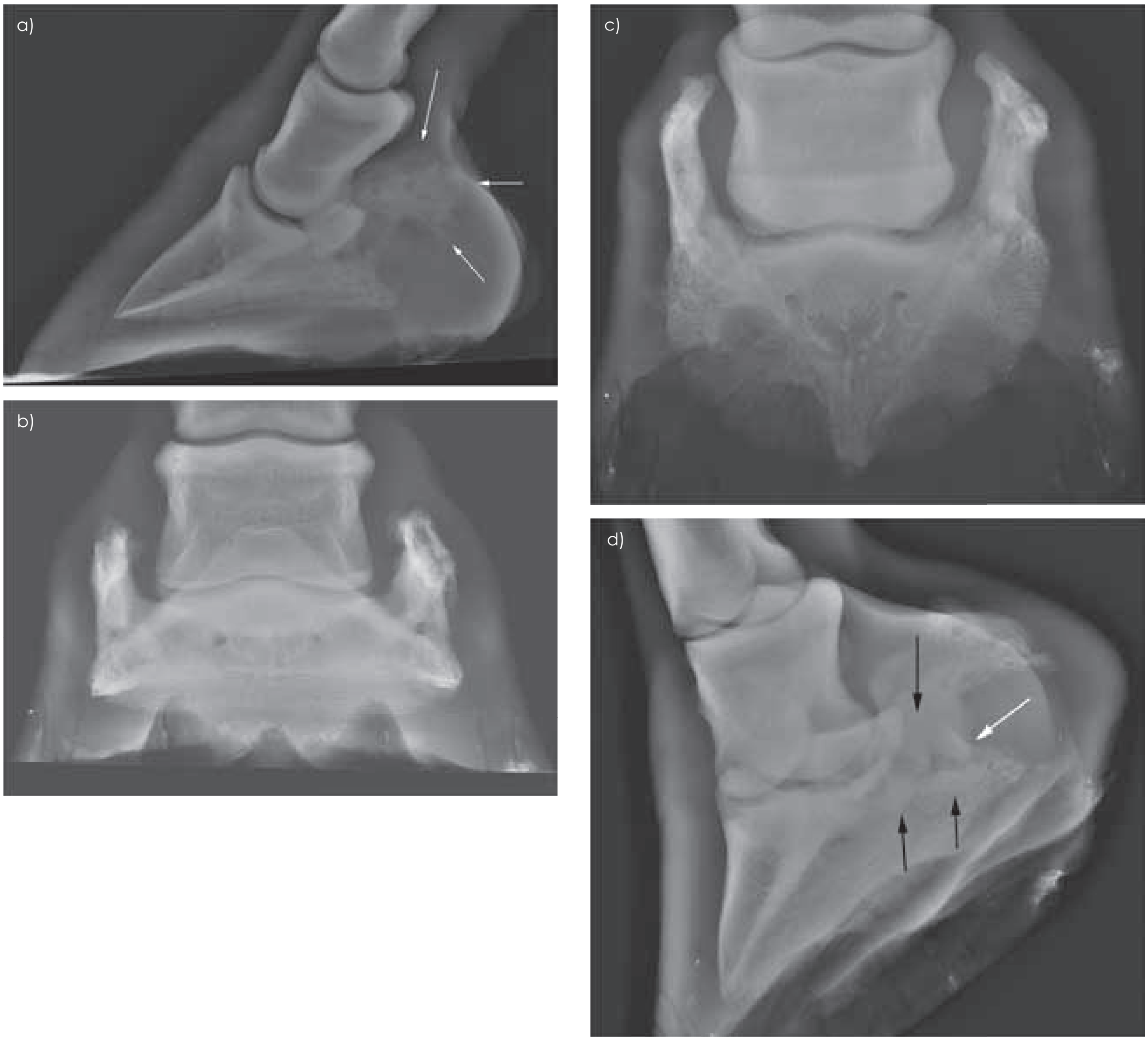


***Fig 2:** Lateromedial (LM) a), dorsopalmar (DPa) b), dorsoproximal-palmarodistal oblique (DPr-PaDiO) c) and dorsomedial-palmarolateral oblique (DM-PaLO) d) radiographic views of a foot. Medial is to the left. There is extensive ossification of the cartilages of the foot. Note the palmar extension of the ossified cartilages proximally (arrows). In the DPa view (b) the lateral ossified cartilage is wider than the medial cartilage of the foot. In the DPr-PaDiO view (c) there is diffuse increased opacity throughout the medial ossified cartilage; there is more focal increased opacity in the bend of the lateral ossified cartilage. In the DM-PaLO view (d) there is an irregular radiolucent line at the base of the ossified cartilage (white arrow) representing either the junction between separate ossification centres or possibly an old fracture. Note the generalised increased radiopacity proximal and distal to the radiolucent line (black arrows).*

cartilage of the foot (**Fig 3d**). At the junction between SCsO the cortices are regular and of uniform thickness. Towards the palmar aspect of the foot there is often separation present between the ossified cartilage and palmar process of distal phalanx. The chondrocoronal, chondrosesamoidean and chondrocompedal ligaments blend smoothly with the cartilages, and have uniform low signal intensity in T1 and T2 weighted images; occasionally there is mild increased signal intensity in fat suppressed images at their origins.

Nuclear scintigraphic assessment of the cartilages of the foot

In a recent study, radiological and scintigraphic gradings of ossified cartilages of the foot were compared (Nagy *et al*. 2007). Mild RU extended throughout the length of the ossified cartilages of the foot. Radiopharmaceutical uptake ratios were used to compare 3 regions of interest in each cartilage of the foot with a region of interest in the ipsilateral aspect of the distal phalanx (**Fig 4a**). There

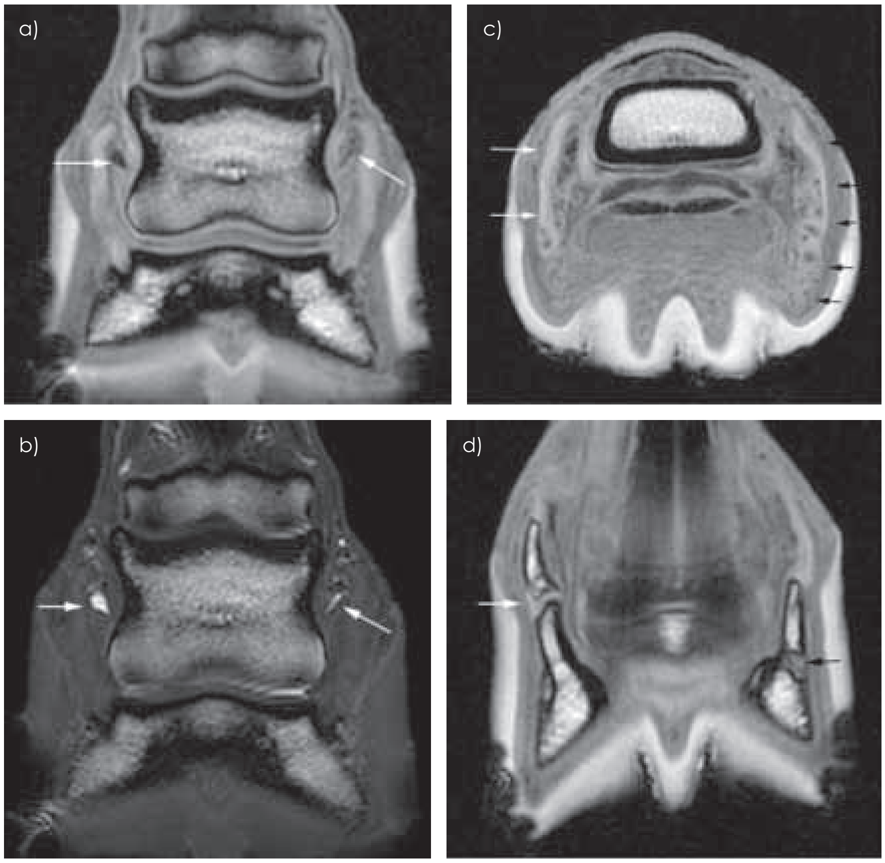


***Fig 3:** Dorsal high-field spoiled gradient echo (SPGR) (T1 weighted) MR image (a) and T2* gradient echo image MR image (b). The cartilages of the foot are not ossified and have slightly heterogeneous high signal intensity in the T1 weighted image and lower signal intensity in the T2 weighted image. Axial to the proximal aspect of each cartilage is a plexus of blood vessels (arrows). c) Transverse high-field SPGR MR image of a different foot to a) and b). Lateral is to the right. The lateral cartilage of the foot (black arrows) is considerably thicker than the medial cartilage of the foot (white arrows) and extends further palmad. Note the multifocal areas of low signal intensity in the palmar two-thirds of the lateral cartilage representing blood vessels. There are also focal areas of low signal intensity axial to the dorsal aspect of each cartilage, representing plexuses of blood vessels. (d) Dorsal high-field SPGR image of a different foot to a)–c). Medial is to the left. There is a separate ossification centre in the medial cartilage of the foot proximally and a smoothly demarcated junction between the ossification centres (white arrow). At the base of the lateral cartilage of the foot there is a region of intermediate signal intensity in the junction between separate ossification centres (black arrow).*

was a proximal-to-distal increase in the RU ratios in both medial and lateral cartilages of the foot. Thus there was relatively greater RU in the region of interest at the base of each ossified cartilage, compared with RU proximally.

In feet in which one cartilage had a high ossification grade and the other was less ossified, RU ratio at the base of the cartilage for the less ossified side was significantly lower than for the other, indicating increased modelling at the base of the more extensively ossified cartilage. If one cartilage of the foot is extensively ossified and the other one is not, forces mediated by ligamentous attachments to the cartilages may be transmitted differently through a rigid osseous structure, compared with an unossified cartilage. This may result in increased stress, modelling, and risk for bone trauma (**Figs 4b–d**) or fracture at the base of the unilaterally extensively ossified cartilage, compared with 2 symmetrically ossified cartilages. Given that there is usually a correlation between the radiological grade of the medial and lateral cartilages of the foot and left right symmetry, marked asymmetry between cartilages may be a risk factor for injury.

Injuries of the cartilages of the foot and related structures

Clinical assessment

The cartilages of the foot are largely encased within the hoof capsule but their proximal extremities are palpable on the dorsomedial and dorsolateral aspects of the pastern, just proximal to the coronary band. However, palpation is not a reliable indicator of the extent of ossification, which can only be determined radiologically. In most horses with injury of a cartilage of the foot, there are no localising clinical signs, except in the presence of infection.

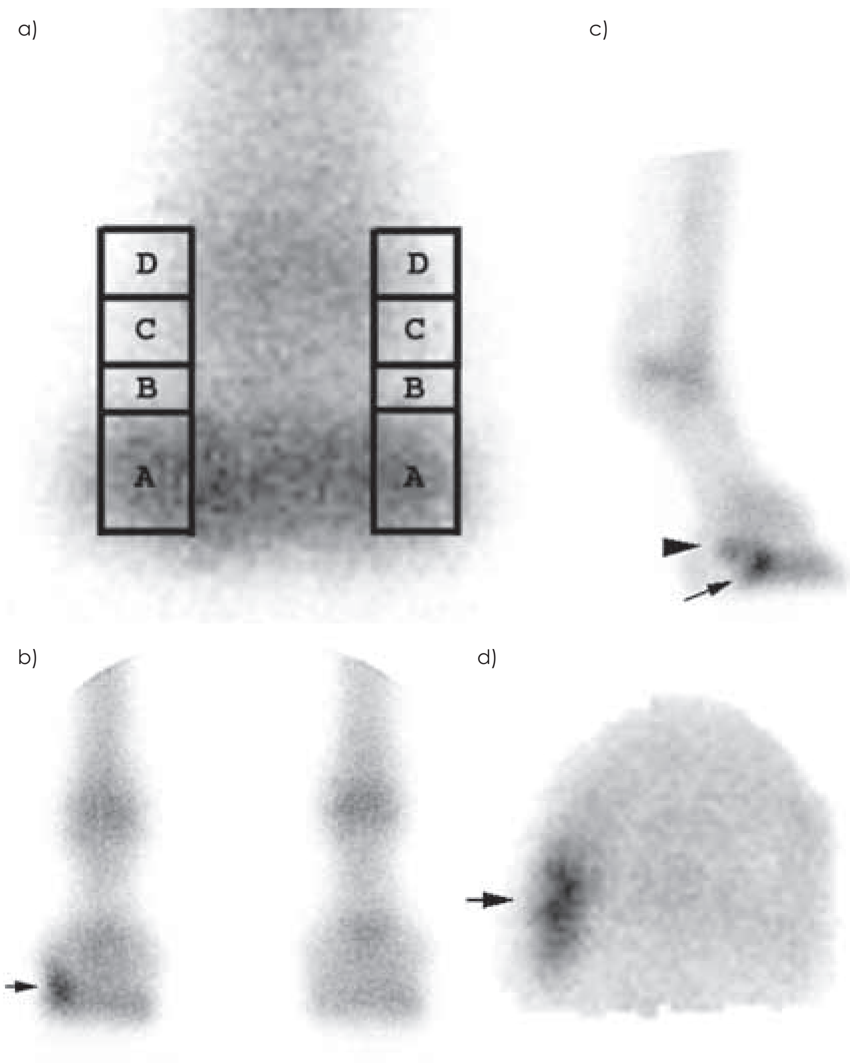


***Fig 4:** a) Dorsal scintigraphic image to show 4 regions of interest A in the distal phalanx and B, C and D overlying the cartilages of the foot. The ratio of counts per pixel for each of D, C and B compared with A was highest for B/A. In a normal foot there is mild radiopharmaceutical uptake in the cartilage of the foot. b–d) Dorsal (b) (right forelimb is to the left), lateral (c) and solar scintigraphic images of a horse with trauma to the base of the lateral ossified cartilage of the foot. There is focal intense increased radiopharmaceutical uptake (IRU) in the base of the lateral ossified cartilage and in the lateral aspect of the distal phalanx (arrows). Note also the mild IRU in the more proximal aspect of the lateral ossified cartilage in the lateral image (arrowhead).*

Extensive ossification of the cartilages of the foot has been anecdotally associated with shortening of stride and, in narrow feet with little room for expansion, it has been suggested to cause lameness; however, there is little documented evidence to support these claims. Nonetheless, there is growing evidence that horses with either marked asymmetry of ossification of the cartilages of the foot within a foot or extensive symmetrical ossification may be at more risk of injury of the ossified cartilage or the ipsilateral aspect of the distal phalanx, compared with horses with no or mild ossification (Dyson and Murray 2010). An association between PSO and collateral desmopathy of the DIP joint has also been demonstrated (Mair and Sherlock 2008; Dyson *et al*. 2010). This supports the earlier observations of O'Connor (1944) that draught horses with extensive ossification of the cartilages of the foot were likely to experience recurrent lameness if worked fast on the roads.

Diagnosis of injury of an ossified cartilage is dependent on responses to local analgesic techniques, radiography and nuclear scintigraphy and, in some horses, MRI. Lameness associated with injury to a cartilage of the foot may be only mild or moderate, although at the time of acute onset may be more severe (Dakin *et al.* 2006; Dyson and Murray 2010). Lameness is generally worse on a circle compared with straight lines. Although lameness may be improved by perineural analgesia of the palmar digital nerves, usually palmar nerve blocks performed at the base of the proximal sesamoid bones are required to abolish the lameness and occasionally lameness is only resolved after palmar and palmar metacarpal nerve blocks (at the

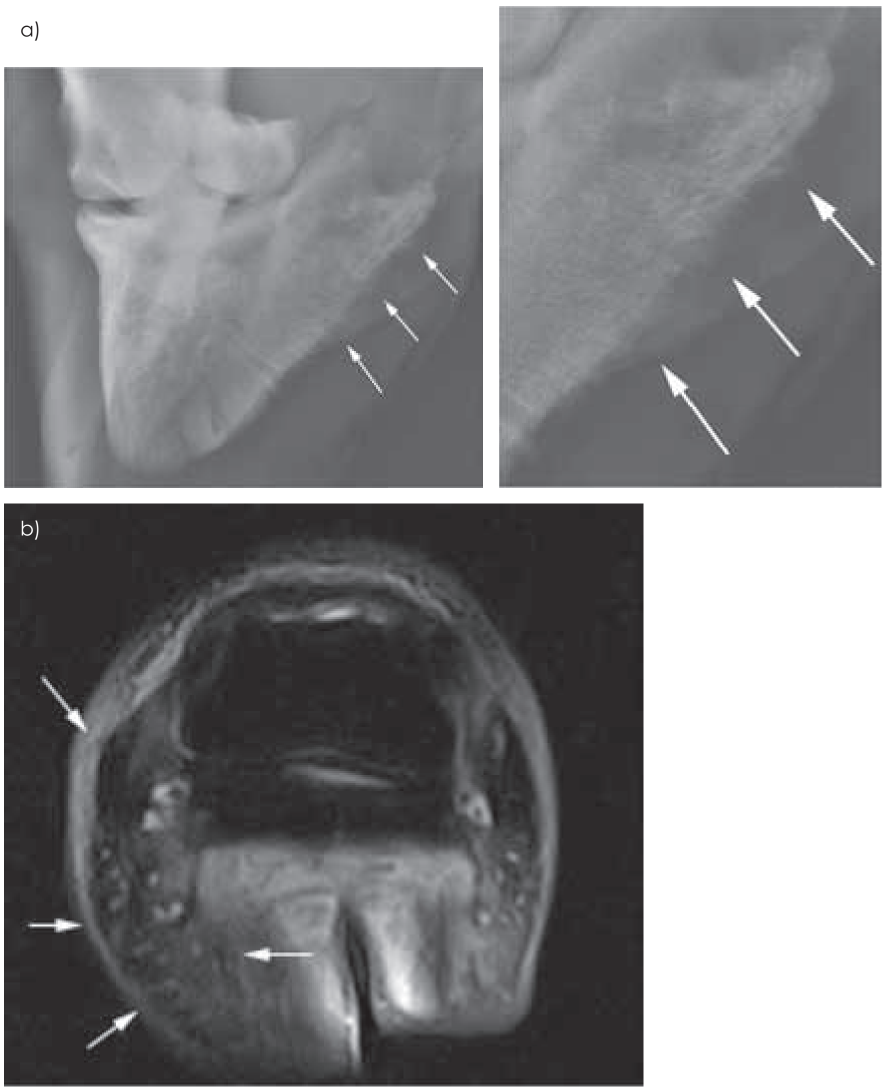


Fig 5: a) Dorsolateral-palmaromedial oblique view of a foot. Note the irregular distal aspect of the lateral palmar process of the distal phalanx (arrows). The horse had an extremely low collapsed heel and chronic lameness. b) Transverse low-field short tau inversion recovery MR image of the same foot as in a). Lateral is to the left. The lateral cartilage of the foot is substantially thicker (arrows) than the medial cartilage. Both cartilages are hypervascular in the palmar half and there is diffuse increased signal intensity throughout the lateral cartilage of the foot and in the palmar half of the medial cartilage of the foot.

junction of the proximal three-quarters and distal one-quarter of the metacarpal region) (Dyson and Murray 2010). Intra-articular analgesia of the DIP joint usually has little effect on the lameness. In horses with uniaxial injuries, an ipsilateral unilateral palmar nerve block may improve the lameness (Dakin *et al.* 2006; Dyson and Murray 2010).

Injury of unossified cartilages of the foot

Primary injuries of unossified cartilages ± related ligaments (chondrocoronal and chondrosesamoidean) of the foot are unusual, but have been seen in a small number of horses (S. Dyson, unpublished data; M. Schramme, personal communication 2009). Diagnosis was dependent on MRI. In 3 horses with low collapsed heels and a large body size relative to foot size and in one horse with markedly asymmetrical heel bulbs, the affected cartilage(s) were markedly thickened, had irregular contours (especially abaxially), were hypervascular and had diffuse increased signal intensity in fat suppressed images, which extended into the ipsilateral aspect of the distal phalanx (**Fig 5**).

One horse with *grade 0* ossification of the medial cartilage of the foot had reduced signal intensity at the base of the cartilage and throughout the medial palmar process of the distal phalanx in T1 and T2 weighted images and increased signal intensity in fat suppressed images, consistent with mineralisation and bone trauma. There was marked enlargement of the medial chondrocoronal ligament with increased signal intensity in fat suppressed images (S. Dyson, unpublished data) (**Fig 6**).

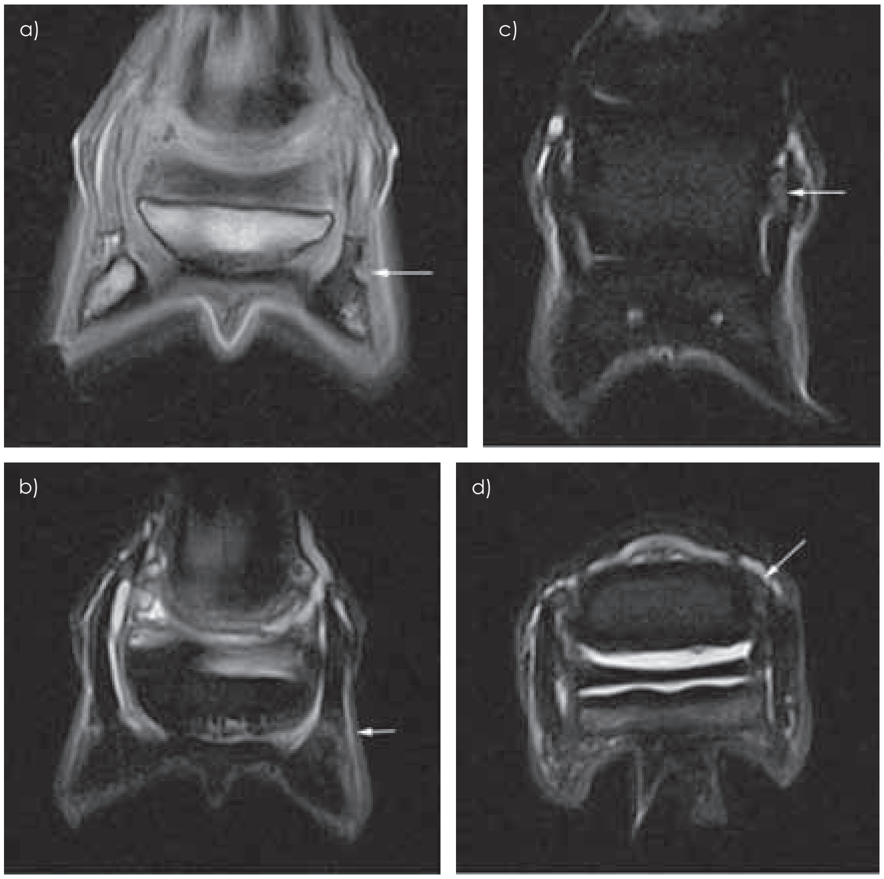


***Fig 6:** (a–d) Dorsal low-field T1 weighted gradient echo (a), dorsal short tau inversion recovery (STIR) (b and c) and transverse STIR (d) MR images of an 8-year-old international showjumper with acute onset right forelimb lameness of several weeks duration. Medial is to the right. In a) there is diffuse decreased signal intensity in the base of the medial cartilage of the foot (arrow) and extending into the distal phalanx. This was also present in T2 weighted images and is consistent with mineralisation. In b) there is focal increased signal intensity at the base of the medial cartilage of the foot (arrow) consistent with trauma. In c) and d) the chondrocoronal ligament (arrows) is thickened and has diffuse increased signal intensity.*

Mineralisation of ossified cartilages of the foot, trauma at the junction between separate centres of ossification and trauma or fracture at the base of an ossified cartilage of the foot

Injury of the junction between SCsO, fractures of an ossified cartilage, usually at the base, and more generalised trauma of an ossified cartilage have been described as primary causes of lameness seen in association with an ossification grade of ≥3 (Dakin *et al*. 2006; Dyson and Murray 2010). These are relatively uncommon causes of lameness; trauma or fracture of an ossified cartilage was identified as primary injury in 24 of approximately 4500 horses (0.53%) undergoing lameness investigation over 9 years (2001–2009) (Dyson and Murray 2010). The diagnosis was based on radiological and scintigraphic findings in 12 horses; the other 12 horses also underwent MRI. Injury diagnoses are summarised in **Table 2**. Sixteen horses (66.7%) sustained injury to the lateral ossified cartilage and 8 horses (33.3%) suffered injury to the medial ossified cartilage. The following description summarises the findings from these and other lame horses (total number = 78) with ≥*grade 3* ossification of one or both cartilages of the foot, which are described in more detail elsewhere (Dyson and Murray 2010).

Fifteen of 32 horses (46.9%) with collateral desmopathy of the DIP joint in association with ≥*grade 3* ossification of the cartilages of the foot also had evidence of trauma of one or both ossified cartilages, characterised by focal or diffuse regions of increased signal intensity in fat suppressed images (Dyson and Murray 2010). Seven of 22 horses (31.8%) with other causes of foot pain determined using MRI in association with ≥*grade 3* ossification of one or both cartilages of the foot also had evidence of trauma of an ossified cartilage of the foot (Dyson and Murray 2010). Cob-types, crossbreeds (especially Thoroughbred cross Irish Draught) and other horses with a high bodyweight: height ratio were most at risk. General purpose riding horses were overrepresented compared with the normal clinic population (Dyson and Murray 2010). The majority of horses were middle-aged geldings. Horses with at least one ossified cartilage ≥*grade 4* predominated.

TABLE 2: Summary of injuries sustained by horses (n = 24) with primary injuries of ossified cartilages of the foot. *Group 1* underwent radiography and nuclear scintigraphy but not magnetic resonance imaging (MRI). *Group 2* underwent radiography, nuclear scintigraphy and MRI. Injuries of the lateral ossified cartilage (n = 16) occurred more frequently than medial injuries (n = 8)

	Group 1		*Group 2*		
Diagnosis	Lateral	Medial	Lateral	Medial	Total
Trauma at base of an ossified cartilage	2	2	0	0	4
Fracture or trauma to the junction between separate ossification centres at the base of an ossified cartilage	4	2	4	1	11
Trauma to the junction between separate ossification centres in the mid shaft of an ossified cartilage	1	0	2	0	3
Generalised trauma to an ossified cartilage	0	0	2	3	5
Focal trauma to the proximal aspect of an ossified cartilage	1	0	0	0	1

A clear radiolucent line at the base of an ossified cartilage surrounded by osseous modelling was indicative of a fracture (**Fig 7**). Diagnosis was substantiated by nuclear scintigraphy demonstrating focal intense IRU correlating anatomically with the fracture site (**Fig 7**). It was not always possible to differentiate between a fracture or trauma to the junction between SCsO. Moreover, not all fractures were detected radiologically and MRI was required, although at the base of the ossified cartilage clear differentiation between trauma to the junction between SCsO and a fracture was again not always possible. Modelling at the base of an ossified cartilage combined with focal IRU, supported by increased signal intensity in fat suppressed images was defined as trauma to the base of an ossified cartilage. Osseous modelling around the junction between SCsO in the mid shaft of an ossified cartilage detected radiologically, associated with IRU reflected likely instability or trauma (**Fig 8**). Trauma was supported by MRI findings, including increased signal intensity in fat suppressed images at the opposing ends of the SCsO. Other radiological findings included mediolateral thickening of an ossified cartilage (**Fig 9a**), irregular cortical contours, heterogeneous radiopacity, or focal areas of increased opacity especially distally, ill-defined transverse radiolucent lines, especially at the base of an ossified cartilage. Careful evaluation of all radiographic projections was crucial because some fractures were only evident in one projection. Other MRI findings included focal or diffuse areas of increased signal intensity in the injured ossified cartilage in fat suppressed images (**Fig 9b**).

In horses examined using MRI there were focal or diffuse areas of decreased signal intensity in both T1 and T2 weighted images in the injured ossified cartilage (**Fig 9c**), consistent with mineralisation in 50% of limbs with either primary injury of an ossified cartilage (6/12) or collateral desmopathy of the DIP joint (16/32) in association with ≥*grade 3* ossification of the cartilages of the foot. Whether such mineralisation reflects a response to chronic trauma or is a physiological response is not known. It may further stiffen an ossified cartilage and alter force transmission through the ossified cartilage and possibly increase the risk of injuries of the cartilages themselves or closely related osseous and soft tissue structures. Extensive ossification reduces the flexibility and capacity for energy dissipation of the cartilages. The predilection for fractures of ossified cartilages at their base may be explained by maximum stress/or strain concentration at this point. The junction between SCsO is a potential weak link. Occasionally, IRU has been seen at the junction between SCsO in the nonlame limb of a bilaterally lame horse, indicating that this may be a point of stress concentration (Dyson and Murray 2010). In such horses there is usually less reactive change seen around the junction on MR images compared with the horses described with injury and lameness.

Trauma of the distal phalanx associated with ossification of the cartilages of the foot

Alterations in signal intensity in the ipsilateral aspect of the distal phalanx were identified in 7/12 horses (58.3%) with a primary injury of an ossified cartilage of the foot (Dyson and Murray 2010). This was characterised either by diffuse areas of hypointense signal in T1 and T2 weighted images consistent with mineralisation or areas of hyperintense signal in fat suppressed images, consistent with bone trauma (**Fig 9d**). One horse had an incomplete fracture of the axial aspect of the distal phalanx. Thirteen of 32 horses (40.6%) with collateral desmopathy of the DIP joint in association with ≥*grade 3* ossification of one or both cartilages of the foot also had evidence of abnormal mineralisation or bone trauma of the distal phalanx. In both groups the presence of active bone modelling was generally supported by IRU in the corresponding anatomical location.

These osseous changes may be related to altered force distribution associated with ossification of the cartilages of the foot. An association between PSO of the cartilages of the foot and injury of the distal phalanx was previously demonstrated in a MRI study of 462 horses with foot pain; there was a significant association between PSO of the maximally ossified cartilage and injury of the distal phalanx (Dyson *et al*. 2010). Although there was no statistically significant association between asymmetrical ossification of the cartilages of the foot and distal phalanx injury, this may have reflected the small number of horses with differences in ossification grade of ≥2 between medial

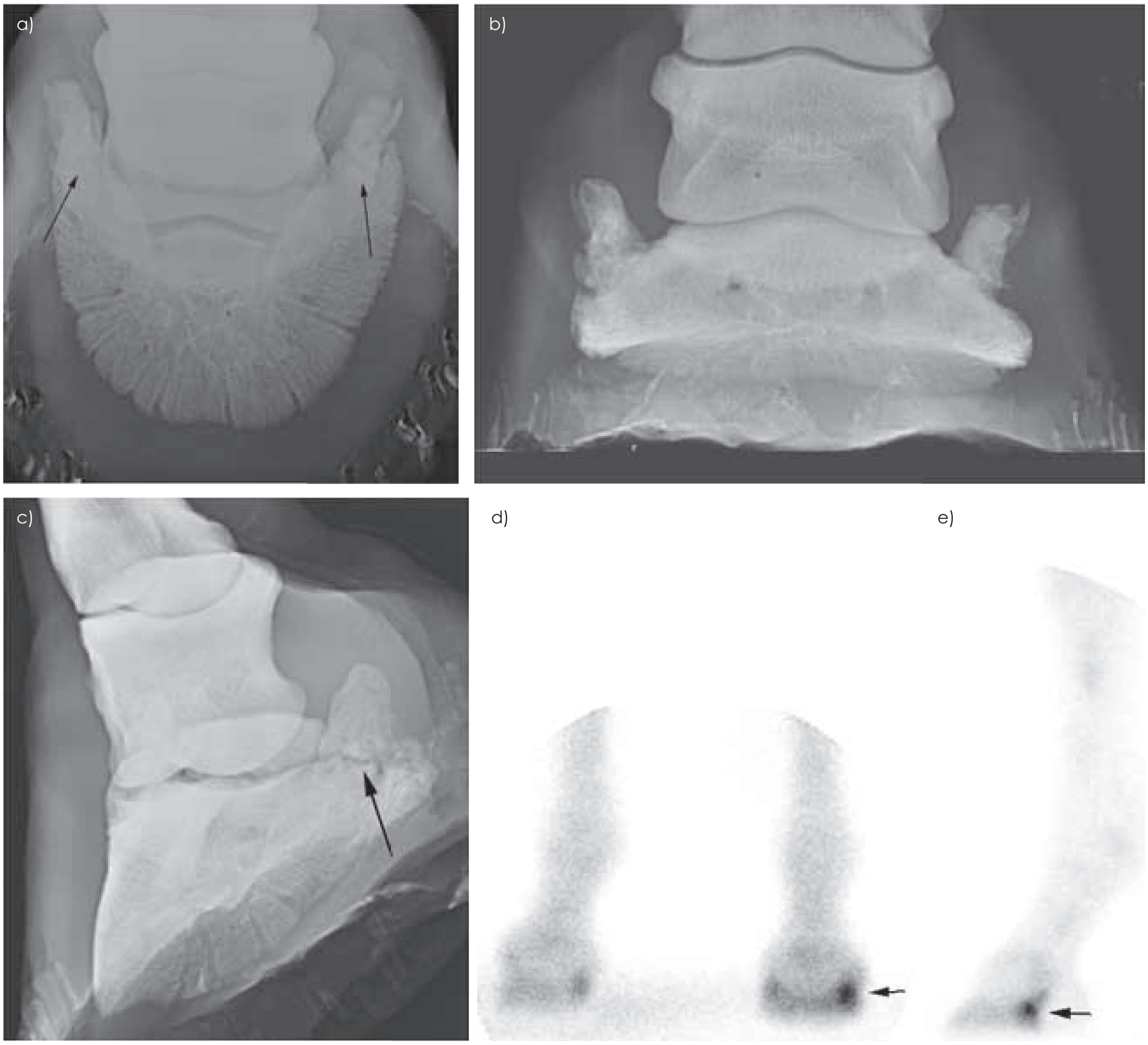


***Fig 7:** a–c) Dorsoproximal-palmarodistal oblique (a), dorsopalmar (b) and dorsolateral-palmaromedial oblique radiographic views of a foot. Lateral is to the right. In a) there are ill-defined radiolucent lines (arrows) in the palmar aspects of the distal phalanx. In b) there is generalised increased opacity in the lateral cartilage of the foot. In c) there is an irregular radiolucent line at the base of the lateral ossified cartilage (arrow). This was not present medially. d) and e) dorsal (d) (left forelimb is to the right) and lateral (e) scintigraphic images of the same horse illustrated in a)–c). There is focal intense increased radiopharmaceutical uptake at the base of the lateral ossified cartilage.*

and lateral and also the exclusion of horses, which did not undergo MRI because of the presence of obvious radiological abnormalities of the distal phalanx. Marked asymmetry in ossification of the medial and lateral cartilages of the foot is unusual (Ruohoniemi *et al*. 1993; Down *et al*. 2007) and may highlight the potential for the presence of a related injury.

Injuries of associated ligaments

Injuries of the chondrocoronal and/or chondrosesamoidean ligaments were characterised by increased size, loss of demarcation of margins and increased signal intensity in fat suppressed images (**Figs 6c** and **d**), or evidence of entheseous reaction at their origin on the cartilages of the foot seen as increased signal intensity in fat suppressed images or irregularities of the axial cortex (Dyson and Murray 2010). These were seen in horses with ≥*grade 3* ossification of one or both cartilages of the foot with both primary injuries of the ossified cartilages of the foot (7/12, 58.3%) and collateral desmopathy of the DIP joint (8/32, 25.0%), but not in association with other injuries of the foot.

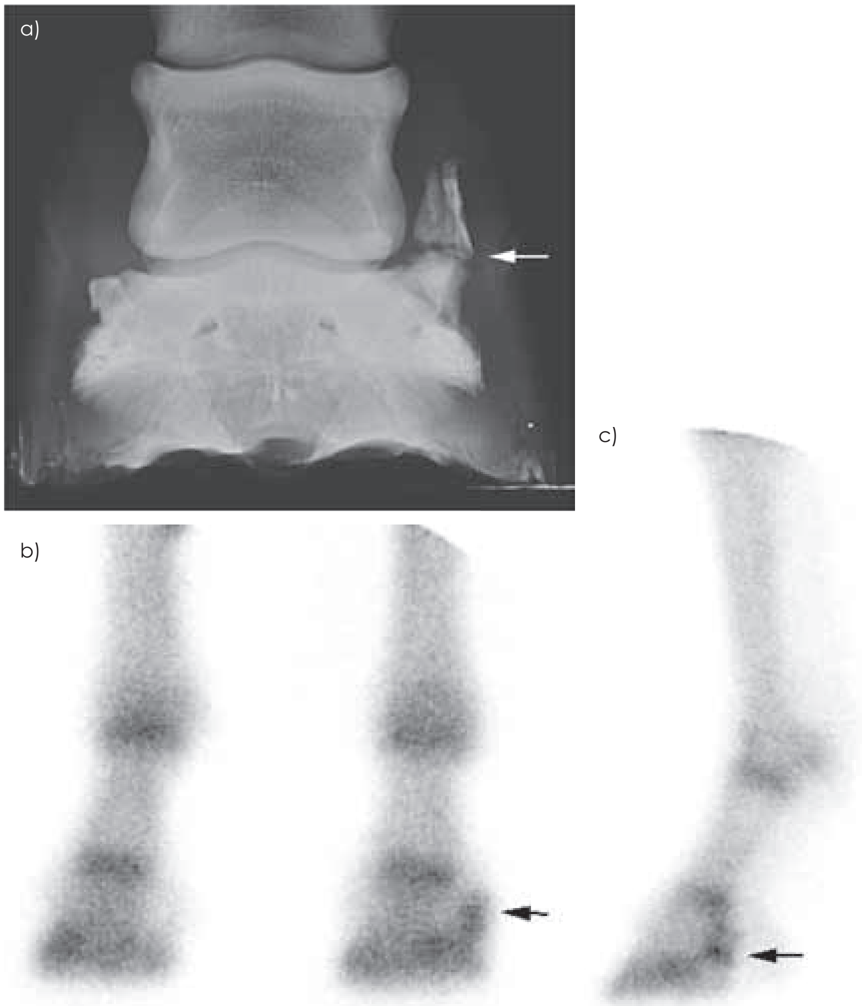


Fig 8: a) Dorsopalmar radiographic view of a foot. Lateral is to the right. There is a separate centre of ossification proximally in the lateral ossified cartilage of the foot. There is a smooth outline of the separate ossification centres at their junction (arrow). The lateral ossified cartilage has generalized increased opacity distally. b and c) Dorsal (b) (the left forelimb is to the right) and lateral (c) scintigraphic images of the same foot as in a). In the dorsal image there is diffuse moderate increased radiopharmaceutical uptake (IRU) throughout the lateral ossified cartilage of the left forelimb. In the lateral image there is focal intense IRU around the junction between the ossification centres of the lateral ossified cartilage (arrows). The radiopharmaceutical uptake appears more intense in the lateral image because the gamma camera was closer to the limb during image acquisition compared with the dorsal image. Trauma at the junction between the separate ossification centres was confirmed by MRI. Lameness was abolished by a uniaxial palmar nerve block performed at the base of the lateral proximal sesamoid bone.

Treatment and prognosis

All horses with primary injuries of an ossified cartilage of the foot were treated by rest for a minimum of 3 months, combined with corrective trimming to correct any imbalance and use of an open broad-web shoe or a bar shoe. Follow-up radiography was performed in those horses with radiological evidence of a fracture, and partial or complete osseous union was seen at 3 months after injury. Fifteen of 21 horses (71.4%) for which follow-up was available returned to full athletic function, with a follow-up period after return to work of 6 months to 4 years. Three of these horses subsequently developed other foot-related lameness 9–12 months after resuming full work. Six horses remained slightly lame but were suitable for light work. Three horses are still convalescing.

Conclusions

The presence of uniaxial or biaxial ossification of the cartilages of the foot should not be discounted as irrelevant in a lame horse, especially if extensive. Consideration should be given to primary injury of an ossified cartilage, injury of the chondrosesamoidean or chondrocoronal ligaments, trauma of the distal phalanx and desmopathy of the CLs of the DIP joint. Moreover, injuries of the cartilages of the foot and related structures can occur in the absence of ossification.

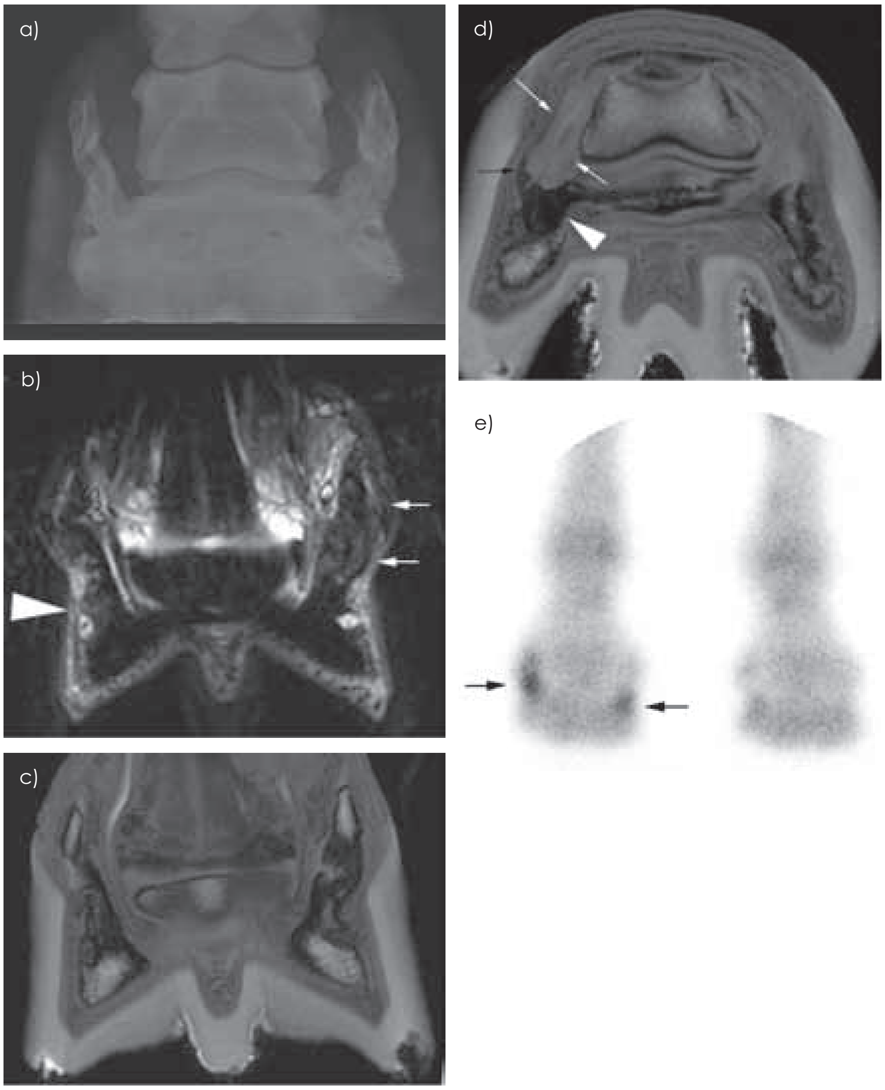


Fig 9: Dorsopalmar radiographic view (a), dorsal short tau inversion recovery (b), dorsal T1 weighted spoiled gradient echo (SPGR) (c) and transverse SPGR (d) high-field MR images of the right forelimb of a horse with right forelimb lameness only apparent on the left rein when lunged on a firm surface. Lateral is to the right. There is extensive ossification of the cartilages of the foot. The lateral cartilage of the foot is wider than the medial. There is diffuse increased signal intensity in the lateral ossified cartilage (arrows) and increased signal intensity at the base of the medial ossified cartilage (arrowhead) in b). There is reduced signal intensity throughout a large proportion of the length of both the medial and lateral ossified cartilages in c), also seen in T2 weighted images and consistent with mineralisation. The periligamentar tissue around the medial collateral ligament of the distal interphalangeal joint is substantially enlarged (white arrows); there is entheseophyte formation on the distal phalanx (black arrow) and diffuse decreased signal intensity in the medial aspect of the distal phalanx distal to the ossified cartilage (white arrow head) in d). e) Dorsal scintigraphic image of the front feet of the same horse as in a–d. The right forelimb is to the left. There is focal intense IRU in the lateral ossified cartilage of the right forelimb and at the base of the medial ossified cartilage (arrows).

It is suggested that on the basis of our recent advances in knowledge, the identification of extensive ossification of the cartilages of the foot either uniaxially or biaxially at a prepurchase examination should be documented and the potential clinical significance discussed with the purchaser. While extensive ossification may be a normal variant in some breeds, it is not usual in most sports horse breeds, and may be a risk factor for future lameness.

Acknowledgements

We thank the many referring veterinary surgeons without whom the referenced studies would not have been possible; also Shelley Down, Kate Robson, Stephanie Dakin (former interns) and Venetia Brown (visiting veterinary student) for assistance with data acquisition.

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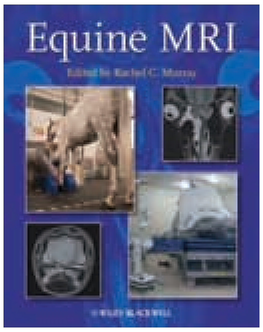

EQUINE MRI

***Editors:* R. C. Murray**

***Publisher:* Wiley-Blackwell**

EVJ price: £90.00

BEVA members price: £81.00

Since its introduction to equine veterinary medicine in the late 1990s, MRI has established an essential and rapidly expanding niche for clinical investigations in the horse.

Equine MRI, edited by Rachel C. Murray, is the first and only comprehensive reference book that covers this field. There are 24 contributors from either private institutions or universities in the UK, Europe or the USA.

At 592 pages, the text consists of 4 sections, subdivided into 25 chapters.

Section A has 4 chapters which are dedicated to the principles of MRI in horses. The introductory chapter explains the basic physics of how the image is produced and how it is influenced by scanner settings and the environment. This is achieved without delving into the exotic quantum physics and complicated mathematics required to accurately describe the MR phenomenon. Two subsequent chapters in this section outline practicalities and image acquisition for both high-field MRI and low-field MRI, highlighting the differences, advantages and disadvantages of the 2 systems. The chapter on high-field MRI includes sub-chapters on the unique general anaesthetic requirements for MRI and the use of MRI contrast agents for orthopaedic conditions and neurological diseases. The last chapter in this section is dedicated to image interpretation and artefacts. It describes the basic MR image appearance and gives an overview of the standard normal tissue patterns seen and typical alterations in tissue MR characteristics seen with pathological change. The numerous artefacts which can occur commonly in MR images are well described with accompanying image examples.

Section B consists of 7 chapters, each describing the normal MRI anatomy of the foot and pastern, fetlock, metacarpus and metatarsus, carpus, tarsus, stifle and head.

Section C describes MRI diagnosed pathology of the regions described in *Section B*. Comprising more than one-third of the book, its content is the raison d'être for performing equine MRI. Some of the interesting findings in regions other than the foot emphasise the progressive development and increasing diagnostic value of MRI.

Section D describes the clinical management and outcome of the MRI diagnosed conditions. It shows some of the benefits of earlier detection and how more accurate characterisation of the nature of various injuries allows more targeted management, more accurate surgical planning in some cases and a more accurate prognosis in many cases. It also highlights the overall lack of evidence-based medicine leaving many missing parts of the jigsaw. There is a lot of variability between chapters in this section. Some provide information restricted to limited MRI experience and few publications, and one chapter describes and references clinical management of many of the commonly recognised conditions in the region without direct reference to MRI in a number of these.

The occasional missing annotation and typographical error does not detract from the quality of a comprehensive reference text, which signals the current understanding of equine MRI. It provides a substantial base upon which future editions will surely be built. Anyone with an interest in equine diagnostics should have a copy.

R. Malton
Dubai Stable Veterinary Clinic, Dubai, United Arab Emirates.