Clinical Examination, Differential Analgesia and Imaging Modalities for Investigation of Distal Limb Lameness

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Introduction

Diseases of the front feet are the most common cause of lameness in horses. A survey of 43,500 lame horses in general veterinary practice in the UK in the early sixties, found the foot to be the cause of the lameness in over 30% of horses. A more recent study estimated that the navicular bone alone was responsible for approximately one-third of chronic lameness in horses. Lameness associated with the fetlock region is also extremely common in horses. In a recent survey of causes of lameness in different horse breeds, synovitis or osteoarthritis of the metacarpophalangeal joint was consistently listed as one of the 10 most common causes of lameness in all categories of Sport Horses surveyed.

The diagnosis of lameness depends primarily on a detailed clinical evaluation, including careful analysis of response to regional analgesia, but it is then necessary to choose the most appropriate imaging modality (or modalities) to use to make a final diagnosis.

Clinical Examination

A methodical approach to clinical examination of the distal portion of a horse’s limb should include step-by-step careful visual evaluation, digital palpation, application of hoof testers, measurement of the response to physiological stress tests (i.e., flexion, extension, torque) and evaluation of the effect of different ground surfaces, flexion, circling, and direction-of-going on the degree of lameness.

The foot is an intricate organ with specialised epidermal and dermal structures, 3 synovial cavities, 2 tendons, 6 ligaments and 3 bones as well as many other related structures. A thorough appreciation of the anatomical detail of this organ is an absolute requirement for understanding and interpreting the clinical and imaging observations made during the course of an examination. The astute clinician hopes that he can gain insights from a detailed examination into the exact location and cause of the horse’s lameness and this is to be encouraged. Even though clinical signs can be highly indicative of some foot diseases however, it is worth remembering that many foot problems share similar clinical signs.
**Visual inspection**

The human eye finds symmetry esthetically more pleasing, and therefore, asymmetry is often readily detected. Anatomical symmetry is generally taken as a measure of soundness. Symmetry is disturbed by swelling, atrophy, deformation, and changes caused by stresses of asymmetrical loading. Visual evaluation of the distal portion of the limb relies heavily, therefore, on recognition of asymmetry between the lateral and medial aspects of the same limb and between contralateral limbs.

Asymmetrical morphology of the feet is usually acquired as a consequence of chronic lameness resulting in decreased weight-bearing in the lame limb. The relatively overloaded (i.e., sound) foot acquires a more shallow toe angle, as well as a larger circumference of the solar margin and a larger width of the hoof. The relatively underloaded (i.e., lame) foot becomes more upright (i.e., steeper angle of the toe and heel) and narrow (i.e., smaller width and smaller circumference of the solar margin). This asymmetry, once acquired, remains present for a long time, even after the original lameness has resolved.

A subjective visual impression of swelling is often best validated by including objective measurements in the examination protocol. A simple measuring tape can produce objective figures that can be compared to the contralateral limb or used as reference values for comparison during follow-up examinations. It can be surprising how poorly measurements of perceived swelling compare to the subjective clinical observation.

The distal portion of the limb is visually inspected with the horse standing squarely and bearing weight evenly on both front limbs. Subsequently, the limb is lifted, the foot cleaned, and the integrity of the palmar structures of the foot evaluated.

Visual highlights and external deformities that should be detected during this part of the examination include dorsopalmar and lateromedial foot imbalances, traumatic or surgical scarring of the skin, bony exostoses, suspensory ligament branch injuries, bowed tendon (i.e., SDFT at the fetlock, DDFT in the pastern), desmitis of the annular ligaments, joint and digital sheath swelling, hoof wall defects and deformities (i.e., growth rings, false quarters, grooves, hoof cracks, pyramidal deformation), infections of the sole, frog and frog clefts, and quittor.

**Digital palpation**

To appreciate any deviation from the normal anatomy by careful digital palpation of the anatomical landmarks of the distal portion of the limb, the examiner has to be thoroughly familiar with the normal anatomical features and their incidental variations. When a finding is suspicious, the limb in question should be compared with the contralateral limb.

A methodical digital examination of the distal limb proceeds from distal to proximal, first with the limb weight-bearing, then with the limb lifted, always looking for swellings, defects, temperature changes, and other irregularities. It starts with assessment of the temperature of the hoof wall, the coronary band and the heel bulbs with the palm or the back of the hand. Be aware that the hand can detect temperature differences of 1.5° C and above.
The coronary band is evaluated for its consistency, presence of focal softening or depressions. The amount of filling of the dorsal joint pouch of the DIP joint is estimated from its fluctuation under digital pressure. The palpable elevation at the origin of the collateral ligaments of the DIP joints, which are situated approximately at 10 and 2 o’clock around the circumference of the coronary band, should be symmetrical. The elasticity of the collateral cartilages is compared between lateral and medial and between left and right feet. The skin over the dorsal aspect of the pastern joint should be freely mobile over underlying structures (i.e., joint capsule and periosteum).

There should be an obvious, palpable, proximodistal groove between the palmarolateral (medial) margin of the proximal phalanx and the lateral (medial) border of the digital flexor tendons between the level of the base of the proximal sesamoid bones and the middle scutum.

Horses should not resent focal percussion of the dorsal cortex of the proximal phalanx. There should be no palpable joint swelling, either fluctuant or fibrous, of the fetlock joint capsule. Swelling of the fetlock joint is best assessed over the dorsal aspect of the joint, immediately proximal to the proximal margin of the proximal phalanx, and over the palmarolateral and palmaromedial joint pouches that are situated proximal to the apex of the sesamoid bones and dorsal to the insertion of the lateral and medial branches of the suspensory ligament. Similarly, there should be no palpable swelling of the digital synovial sheath. The landmarks for palpation of the presence of fluctuant filling of the digital sheath are its palmarolateral and palmaromedial pouches proximal to the sesamoid bones, palmar to the insertion of the branches of the suspensory ligament and dorsal to the lateral and medial margins of the flexor tendons. In addition, the palmarodistal pouch should be evaluated over the distal palmar aspect of the pastern, immediately proximal to the heel bulbs. The palmar silhouette of the pastern and fetlock regions is outlined by the annular ligaments and should be smooth and free of swellings or indentations. The lateral and medial branches of the suspensory ligament should be smooth, symmetrical in thickness, pain-free on digital pressure, and the overlying skin should be freely mobile. Focal digital pressure over bony prominences of the margins of the fetlock joint or over the proximal sesamoid bones should not produce pain. The presence of digital pulses should be assessed at the level of the proximal sesamoid bones or over the medial palmar artery in the proximal to middle third of the metacarpal region. Digital arteries can be enlarged without pulsation, or pulsation can be present with varying degrees of enlargement. An increased digital pulse is a good indication of the presence of inflammation in the distal portion of the limb.

With the limb lifted, the stability of heel bulbs should be assessed by grasping each heel bulb with the left and right hands and determining whether movement occurs between the two. The neurovascular bundle should be palpated on either side of the DDF tendon in the distal palmar aspect of the pastern. The skin should be freely mobile in the distal palmar aspect of the pastern, the palmar surface of the DDF tendon should be flat, smooth, and pain-free when focal pressure is applied. There should be no palpable synovial fluid present in the palmar distal pouch of the digital synovial sheath. The normal angle of flexion of the fetlock is approximately 110° to 120° and should be identical bilaterally. Forced flexion of the joint should not be resented.
Hoof testers

The use of hoof testers enables the examiner to rule out the presence of peripheral foot pain associated with the hoof wall, sole, dermal tissues, and digital cushion. Its use for identification of navicular pain is controversial, but generally considered to be unreliable. Examination using a hoof tester is conducted in a methodical fashion, applying focal pressure to the sole and wall in a circumferential movement from the lateral heel across the toe to the medial heel. After exploring the sole, the testers are placed across each side of the frog and the opposite hoof wall. Both hands should be on the testers, and the foot should be immobilized between the knees. The degree of response to application of hoof testers is determined by the size of the testers, the size of the foot, the thickness of the sole, the demeanour of the horse, the amount of pressure applied by the examiner, and finally, the presence of disease. It is important to develop a sense for what is normal variation between horses and for a particular horse and responses between contralateral feet should be carefully compared. In one study, the hoof tester examination had a sensitivity of 45%, a specificity of 50%, a positive predictive value of 50% and an accuracy of 48% for the identification of navicular pain.4

Physiological stress tests

Distal limb flexion tests have been used for many years to localize pain to the region of the fetlock. Even though flexion tests result in exacerbated lameness in most horses with intra-articular disease of the metacarpophalangeal joint, many conditions of the foot and the pastern produce the same effect. In addition, the response to a fetlock flexion test is dependent on the force and time used to perform this test.5,6 Flexion tests can and should be standardized for time and force (FlextestR).5 One study found the optimal force for a flexion test to be 100 N for a duration of 1 minute.5 A slightly positive flexion response (100 N/1 min) in a horse with no other clinical signs or radiographic abnormalities had no clinical significance.5 Other investigators showed that most clinically sound horses have a (slightly) positive flexion test of the distal portion of the limb and that the results of the flexion test increased significantly with age.7 This observation and the lack of long-term consistency of the test cast doubt on the presumption that a positive flexion test may be an indication for subclinical joint disorders and question the possible value of the test as a predictor of future joint-related problems.7 Lameness following a fetlock flexion test is more likely to be clinically significant if the response is markedly different between contralateral limbs.

Extension and flexion tests of the DIP joint and navicular apparatus are performed by placing a 15-20° wooden wedge under the foot resulting in either toe elevation or heel elevation for a period of 1 minute. Toe elevation increases strain in the DDFT, navicular suspensory ligaments and impar ligament, and elevates the compressive force on the navicular bone. Nevertheless, toe elevation tests only have a sensitivity of 55% and a specificity of 42% for the presence of navicular pain.4 Heel elevation reduces strain in the DDFT, impar ligament and navicular suspensory ligament but increases direct impact pressure on the heels. In spite of this, Turner found that heel elevation has a sensitivity of 76% and a specificity of 26% for the presence of navicular pain.4 It has been my observation that several horses with lesions of the DDFT (as identified on MRI), experience worsening of lameness after heel elevation.
Lameness

It is not the purpose of this paper to describe in great detail the gait abnormalities that can be caused by every form of lameness attributed to disease of the distal portion of the limb. As a general rule, pain originating in the distal portion of the limb causes a supporting limb lameness (as opposed to a swinging limb lameness), characterized by the downward motion of the head and neck when the sound (i.e., contralateral) limb strikes the ground. Lameness caused by pain in the distal portion of the limb tends to be worse when the horse is trotted on hard ground than when the horse is trotted on soft ground and is often more noticeable when the horse trots in a circle. Lameness is usually worse when the lame limb is on the inside of a circle than when it is on the outside of a circle.

Differential Analgesia

In recent years, clinical observations, anatomical studies, and results of clinical trials have helped to clarify interpretation of the results of regional, intra-articular, and intrabursal analgesia of the forefoot of horses.

Analgesia of the palmar digital nerves (Palmar digital nerve block)

For many years, a positive response to anesthesia of the palmar digital nerves of lame horses was thought to localize pain to the palmar third of the foot. This premise is no longer valid. Easter et al. found that analgesia of the palmar digital nerves just proximal to the bulbs of the heel alleviated lameness caused by endotoxin-induced pain in the DIP joint, indicating that the palmar digital nerves innervate the entire DIP joint, although exceptions to this finding have been observed in horses with osteoarthritis of the DIP joint, where the distal articular surface and subchondral bone of the middle phalanx are diseased.

Analgesia of the palmar digital nerves just proximal to the bulbs of the heel further desensitizes the entire sole of the foot. It can therefore be concluded that a palmar digital nerve block (PDNB) desensitizes the entire foot, with exception of the skin at the dorsal aspect of the coronary band and the dorsal aspect of the hoof wall. It can further be concluded that the dorsal branches of the digital nerves provide only cutaneous sensory innervation to the dorsal aspect of the digit.

Some clinicians describe the proper site for analgesia of the palmar digital nerves to be anywhere from the proximal margin of the ungular cartilage to the mid pastern region, but others believe that it is important to anesthetize the nerves near the proximal margin of the ungular cartilage. Schumacher et al, however, found that deposition of local anesthetic solution in the mid or proximal portion of the pastern might result in analgesia of the PIP joint of some horses. To avoid the possible complication of desensitizing part of the PIP joint, each palmar digital nerve should be anesthetized by depositing subcutaneously no more than 1.5 mL of local anesthetic solution at, or distal to, the proximal margin of the ungular cartilage.
Analgesia of the palmar digital and dorsal digital nerves (Pastern Ring Block)

It is doubtful if a pastern ring block, performed after a negative response to a PDNB, would result in a positive response because the dorsal branches of the palmar digital nerves contribute little to sensation within the foot. The PDNB will already have anesthetized the entire foot, with exception of the dorsal portion of the coronary band and the dorsal laminae of the foot, (which could be the source of pain in laminitis or other diseases of the dorsal hoof wall).

On the other hand, the use of a pastern ring block at mid pastern level, should be encouraged as an alternative to the abaxial sesamoid nerve block (ASNB). A mid pastern ring block provides an opportunity for desensitization of the middle phalanx and PIP joint without the risk of desensitizing unspecified amounts of the fetlock joint, which is a common occurrence of the ASNB, and complicates interpretation of improvement in lameness following the latter.

Analgesia of the palmar nerves at the level of the fetlock (Abaxial Sesamoid Nerve Block)

Analgesia of the palmar digital nerves and their dorsal branches, at the level of the proximal sesamoid bones (i.e., an ASNB), desensitizes the foot, the PIP joint, middle phalanx and associated soft tissues, the distal and palmar aspects of the proximal phalanx, and possibly the palmar portion of the metacarpophalangeal joint.

Performing the nerve block at the base of the proximal sesamoid bones decreases but does not eliminate the likelihood of partially desensitizing of the metacarpophalangeal joint. Using a small volume of local anesthetic solution (i.e., < 2 mL) and directing the needle distally, rather than proximally, also decreases the likelihood of partial analgesia of the metacarpophalangeal joint.

Analgesia of the distal interphalangeal joint

Mepivacaine HCl administered into the DIP joint desensitizes the DIP joint, the navicular bursa, and the toe region of the sole. When a large volume of mepivacaine HCl (i.e., 10 mL) is administered, the heel region of the sole may also be desensitized.

Local anesthetic solution, administered into the DIP joint may desensitize subsynovial nerves that supply sensory fibers to the navicular bone and its collateral sesamoidean ligaments, or it may desensitize the palmar digital nerves, which lie in close proximity to the palmar pouch of the DIP joint. In addition, Gough et al. found, in a study using cadavers, that local anesthetic solution diffused from the DIP joint into the navicular bursa.

A negative response to intra-articular analgesia of the DIP joint does not eliminate the navicular bone and its related structures as the source of pain and lameness. In a study of 102 horses with chronic foot pain, Dyson found that 21% of horses failed to respond to intra-articular analgesia of the DIP joint but improved significantly after analgesia of the navicular bursa.
If lameness is improved by a PDNB, evaluation of the gait after intra-articular analgesia of the DIP joint with a low volume of mepivacaine HCl (i.e., ≤ 6mL) may help to determine if pain in the soft tissues of the heel region is the cause of lameness. Pain is unlikely to originate from the sole of the heel, if lameness is ameliorated by analgesia of the DIP joint, using a low volume of mepivacaine HCl.

**Analgesia of the navicular bursa**

A study comparing various techniques for inserting a needle into the navicular bursa showed that a method described by Verschooten was the most accurate approach. Using this approach, a 20-gauge, 8.9-cm (3.5-inch), disposable, spinal needle is inserted between the bulbs of the heel just above the coronary band, and the needle is advanced along a sagittal plane aiming for a point 1 cm below the coronary band, midway between the toe and the heel (Fig. 1). The foot can be examined radiographically or ultrasonographically to determine positioning of the needle prior to injection.

![Diagram](image-url)

**Fig. 1.** A 20-gauge, 8.9-cm (3.5-inch), disposable, spinal needle is inserted between the bulbs of the heel just above the coronary band, and the needle is advanced along a sagittal plane aiming for a point 1 cm below the coronary band, midway between the toe and the heel (the navicular position). (Courtesy of Schumacher J, Schumacher J, Schramme M, De Graves F, Smith R, and Coker M (2004) ‘Diagnostic analgesia of the foot.’ Equine Veterinary Education, 16 (3) 159 - 165.)
A positive response to administration of local anesthetic solution into the navicular bursa indicates disease of the navicular bursa, the navicular bone and/or its supporting ligaments, solar toe pain, or disease of the DDFT. Even though analgesia of the DIP joint results in analgesia of the navicular bursa, analgesia of the navicular bursa does not result in analgesia of the DIP joint. Analgesia of the navicular bursa may help to differentiate pain associated with disease of the DIP joint from pain associated with disease of the navicular bone and associated structures. Pain arising from the DIP joint can likely be excluded as a cause of lameness when lameness is attenuated within 10 minutes by analgesia of the navicular bursa.

In addition to experimental findings concerning the effect of analgesia of the navicular bursa, clinical observations indicate that a positive response to intra-articular analgesia of the DIP joint and a negative response to intrabursal analgesia of the navicular bursa incriminate pain within the DIP joint as the cause of lameness. This clinical observation is valid if solar pain can be eliminated as a cause of lameness (Fig. 2).

Fig. 2. Sequential analgesia of the palmar digital nerves, the DIP joint and the navicular bursa, becomes more specific as less structures in the foot are desensitized. An explanation for the observation that analgesia of the navicular bursa does not cause analgesia of the DIP joint is that the site of direct contact between the palmar pouch of the DIP joint and the palmar digital nerves is located at a region proximal to the origin of the deep branches that innervate the DIP joint and the navicular bursa, and that the site of direct contact between the navicular bursa and the palmar digital nerves is located distal to these branches. (Courtesy of Schumacher J, Schramme MC, Schumacher J, et al. (2003) A review of recent studies concerning diagnostic analgesia of the equine forefoot. Proceedings 49th Annual Convention Am. Assoc. Eq. Pract. p 315).
**Analgesia of the digital synovial sheath**

A recent study demonstrated that induced pain in the toe and heel regions of the sole, pain associated with synovitis of the DIP joint and pain associated with synovitis of the navicular bursa were not significantly attenuated by intrathecal analgesia of the digital sheath. It is, therefore, logical to assume that analgesia of the digital synovial sheath desensitizes only structures that are contained within or border on the sheath itself (i.e., SDFT, DDFT, straight distal sesamoidean ligament [SDSL], oblique distal sesamoidean ligament [ODSL], and annular ligaments of the fetlock and pastern).

**The effect of time on interpretation of analgesia of the DIP joint or navicular bursa**

Some clinicians have assumed that improvement in lameness observed within 10 minutes after injection of the DIP joint with local anesthetic solution indicates that lameness is caused by DIP joint pain alone, and that improvement observed more than 10 minutes after injection is caused by diffusion of local anesthetic solution into the navicular bursa or around the nerves providing sensory innervation to the navicular apparatus. This assumption appears to be invalid because a positive response to intra-articular analgesia of the DIP joint has been observed to occur within 5 to 8 minutes of injection in a majority of horses with navicular disease or experimentally-induced navicular bursal pain.

Results of several trials indicate that the effect of intra-articular analgesia of the DIP joint or intra-bursal analgesia of the navicular bursa on lameness should be assessed soon after injection (i.e., within 10 min) because after this period, the structures that are desensitized by diffusion of the anesthetic solution become uncertain.

**Diagnostic analgesia of the digital portion of the DDFT**

Lameness caused by tendinitis of the digital portion of the DDFT can be abolished in only approximately 2/3 to 3/4 of horses, either with a PDNB (72% response), intra-articular analgesia of the DIP joint (68% response) or intrabursal analgesia of the navicular bursa (67% response), though an ASNB is 100% effective in eliminating pain associated with tendinitis of the DDFT. Because lameness caused by disease of the DDFT within the foot occasionally fails to improve significantly after analgesia of the palmar digital nerves, the DIP joint, and the navicular bursa, it is likely that a portion of the DDFT within the foot receives its sensory supply from more proximal deep branches of the medial and lateral palmar digital nerves that enter the digital sheath. Reports of improvement of lameness in horses with lesions of the distal part of the DDFT after intrathecal analgesia of the digital synovial sheath support this hypothesis. Performing intrathecal analgesia of the digital sheath of the DDFT on horses with lameness that is unchanged after analgesia of the palmar digital nerves but resolves after an ASNB, may be useful. Resolution of lameness after intrathecal analgesia of the DDFT sheath justifies suspicion of a lesion in the digital portion of the DDFT.
Diagnostic analgesia of the collateral ligaments of the DIP joint

Lameness caused by disease of the collateral ligaments of the DIP joint often fails to improve significantly after analgesia of the DIP joint itself. Only 24% of 21 horses with MRI evidence of collateral ligament disease showed a significant improvement in lameness after intra-articular analgesia of the DIP joint, and none of the horses improved after analgesia of the navicular bursa. A PDNB, however, improved lameness significantly in 72% of these horses, and all became sound after an ASNB. Consequently, when lameness is abolished by a PDNB but not by analgesia of the DIP joint or navicular bursa, and no radiographic abnormalities of the foot can be detected, clinical suspicion of collateral desmitis of the DIPJ is justified, as long as solar or heel pain can be eliminated by application of hoof testers.

Clinical impressions suggest that the degree of improvement in lameness associated with collateral ligament injury after a PDNB is determined by the extent of the injury and the level at which the palmar digital nerves are anesthetized. The further proximal the level of the injury, the less likely is lameness to be affected by analgesia of the DIP joint or a PDNB. This observation suggests that the deep branches innervating the collateral ligament arise from the palmar digital nerves, proximal to the site where the nerve abuts the palmar pouch of the DIP joint. When there is osseous remodeling at the origin of the collateral ligament at the level of the middle phalanx, analgesia of the palmar digital nerves may need to be performed at the level of the proximal sesamoid bones (ASNB) to abolish lameness associated with proximal enthesopathy of the collateral ligament of the DIP joint.

Intra-articular analgesia of the fetlock joint

Although a positive response to intra-articular analgesia unequivocally places disease in the fetlock joint, not all lameness associated with injuries of the fetlock joint resolves with intra-articular analgesia. Whereas lameness caused by intra-articular fragmentation, synovitis, capsulitis, and osteoarthritis improves or resolves after intra-articular analgesia, lameness caused by extra-articular fractures, injury to the subchondral bone or, peri-articular ligaments will only improve after a low 4-point nerve block.

Several techniques are described for intra-articular analgesia of the fetlock joint. The author prefers the technique described by Misheff and Stover, during which the limb is positioned in partial flexion by holding the foot with one hand, while the needle is introduced in the space between the articular surface of the lateral sesamoid bone and the palmar aspect of the lateral metacarpal condyle. A volume of 10 mL mepivacaine is instilled, and the lameness is assessed after 10 – 15 minutes.

Analgesia of the palmar and palmar metacarpal nerves at the distal third of the metacarpus (i.e., Low-4-point nerve block)

This nerve block may take longer than other nerve blocks of the distal portion of the limb to take effect, and careful assessment of the area of desensitization of the digit, especially the skin over the dorsal aspect of the fetlock, is advisable prior to trotting the horse. Resolution of pain in the
fetlock region is usually more complete after perineural analgesia than after intra-articular analgesia of the fetlock joint.

**Imaging Modalities**

The diagnosis of lameness of the distal portion of the limb depends first on a detailed clinical evaluation, but after this examination, the clinician must decide which imaging modality (or modalities) is most appropriate to make a precise diagnosis. In spite of the development of sophisticated new imaging modalities, our ability to localize pain accurately to specific structures in the digit is still limited.

**Radiography**

Comprehensive discussions of radiography of the foot are provided by many textbooks. Frequently diagnosed causes of chronic lameness of the distal portion of the limb are palmar foot pain, ‘pedal osteitis’, DIP joint pain, navicular pain, and synovitis or osteoarthritis of the fetlock joint. We commonly associate these diagnoses with radiological abnormalities of the DIP joint, the distal phalanx, the navicular bone or the fetlock joint, but often no radiographic lesions can be detected. The interpretation of radiographs of these structures is controversial, and the use of more sophisticated imaging modalities, such as scintigraphy, CT, and MRI, have made it clear that radiography is not a particularly sensitive indicator of disease of the distal portion of the limb.

The diagnosis of navicular disease has traditionally been based on the appearance of the synovial invaginations (i.e., nutrient foramina) along the distal border of the navicular bone. Navicular scoring systems based on the shape, size, and location of synovial invaginations are flawed because they focus on one questionable sign of disease only. Numerous studies have shown that ‘abnormal’ synovial invaginations are poorly correlated with lameness, rarely progress in size, and that their radiographic presence is inconclusive for the diagnosis of navicular disease. Radiological abnormalities more strongly associated with lameness are flexor cortex defects, medullary sclerosis, proximal border remodeling, and loss of medullary trabecular pattern. A more successful navicular radiological grading system is widely used throughout Europe (Fig. 3).

A lateromedial projection of the highest quality is essential for adequate interpretation of the navicular bone. Contrary to popular belief, recent work has suggested that the palmarproximal-palmarodistal oblique projection (i.e., the navicular flexor view) is not an essential requirement for an accurate diagnosis of navicular disease. In addition, the navicular flexor view is a technique-sensitive projection. Imaging of isolated bones has indicated that slight changes in angulation of the central beam relative to the proximodistal axis of the navicular bone result in marked alterations in the thickness of the flexor cortex and the sharpness of the corticomedullary delineation (unpublished data). A comparative study of the navicular flexor cortex using radiography and computed tomography concluded that accurate radiographic evaluation of the flexor central eminence was often difficult and that medullary sclerosis and loss of corticomedullary junction were commonly overinterpreted radiological features on the palmarproximal-palmarodistal oblique projection.
Many specialized radiological projections have been described in the fetlock for detection of proximopalmar/plantar fragments of the proximal phalanx and basilar sesamoid fragments, apical sesamoid fragments, abaxial sesamoid fragments, short incomplete fractures of the palmar aspect of the metacarpal condyles, palmar/plantar osteonecrosis of the metacarpal/metatarsal condyles, and subchondral cystic lesions of the distal aspect of the third metacarpal bone or proximal aspect of the proximal phalanx. The different sites of new bone production in the region of the fetlock can be elucidated from the detailed study of the origins and insertions of the soft tissue structures in this area.30

Considerable work has been done recently to determine the incidence and importance of radiological changes of the fetlock with regard to a horse’s future athletic career.31 The prevalence of osteochondral fragments in Thoroughbred yearlings was 2.1% for the metacarpophalangeal joint and 9.2% for the metatarsophalangeal joint.31 The prevalence in Hanoverian Warmblood horses was 9.5% for the metacarpophalangeal joint and 13.7% for the metatarsophalangeal joint.32 More importantly, the odds for starting a race were 3 times lower for yearlings with supracondylar lysis, the prevalence of which was 4.8%. Odds of starting a race were also 3 times lower for yearlings with enthesophyte formation on the sesamoid bones and 2 times lower for yearlings with dorsoproximal fragmentation of the proximal phalanx in the hindlimb.31
**Ultrasonography**

Diagnostic ultrasonographic images of the collateral ligaments of the DIP joint can be obtained by positioning a 10 MHz linear transducer on the firm part of the dorsolateral and dorsomedial aspects of the coronary band. The normal cross-sectional area of these ligaments has been defined as $0.63 \pm 0.05 \text{ cm}^2$. One study showed a high prevalence of increased cross-sectional area and loss of echogenicity of the collateral ligaments in a group of horses with palmar foot pain. The distal part of the DDFT is most easily visualized from between the heelbulbs in the palmarodistal aspect of the pastern (i.e., transcuneal view), and the normal width of the tendon in this view has been defined as $0.84 \pm 0.1 \text{ cm}$. Ultrasonographic examinations of the DDFT, impar ligament and navicular flexor cortex using a transcuneal view, however, are difficult and rarely rewarding for the first author.

The ultrasonographic examination of the fetlock, which has been described in detail, is mainly performed when injuries of the soft tissue attachments are suspected (e.g., joint, capsule, distal sesamoidean ligaments, suspensory branches, intersesamoidean ligament, collateral ligaments). Ultrasonographic examination of chip fractures in the dorsal aspect of the fetlock joint can help distinguish an acute fracture, which is surrounded by fluid, from a chronic fracture, which is surrounded by synovial proliferation, or from metaplastic soft tissue calcification within the villonodular fold, which is surrounded by synovial proliferation in the proximal aspect of the pouch. Collateral ligament injuries are characterized by enlargement, entheseophyte formation, loss of echogenicity, or any combination of the above. Collateral desmitis of the fetlock was identified ultrasonographically in 21% of horses with lameness localized to the fetlock region. A dynamic, ultrasonographic examination is indicated for horses with digital tenosynovitis with or without annular ligament desmitis, to evaluate the degree of constriction and the presence/absence of freedom of movement of the flexor tendons within the sheath. An ultrasonographic examination of the entire fetlock should always be performed when results of regional analgesia indicate that lameness is arising from this region (i.e., a positive low 4-point nerve block and negative intra-articular analgesia).

**Scintigraphy**

Interpretation of scintigraphic images of the feet is mainly a subjective visual procedure. Quantitative assessment can be performed on solar images, however, and conclusions should be based on comparison of the radiopharmaceutical uptake between the regions of interest (ROI), such as the navicular bone (1), the region of insertion of the DDFT (2), and the toe and wing regions of the distal phalanx (3, 4, 5) (Fig. 4). Normal ratios between these ROIs have been established. Although a significant difference in uptake of radionuclide has been documented in the navicular region of horses with foot pain in comparison with uptake of radionuclide in the navicular region of the normal horses, there is also high incidence of false positive results in horses without foot pain, especially in the region of insertion of the DDFT.

Scintigraphic examination of the fetlock is particularly useful in the identification of ‘occult’ subchondral bone trauma. In one study, scintigraphy helped identify the existence of ‘hot condyles’ as an increasingly common cause of fetlock lameness in racing Thoroughbreds.
investigators proposed that an ROI ratio greater than 3/1 between the plantar aspect of the metatarsal condyles and the midmetatarsal diaphysis was pathognomonic for subchondral bone trauma. A positive bone scan can precede radiographic changes by at least 2 to 3 weeks in horses with stress-related bone injury. Up to 49% of equine athletes with palmar/plantar increased radiopharmaceutical uptake (IRU) in the fetlock joint are without radiological abnormalities. Flexed scintigraphic images are particularly useful in these patients to determine if IRU in the palmar fetlock involves the proximal sesamoid bones or the palmar aspect of the metacarpal condyles.

Fig. 4. Solar scintigraphy of a foot with representation of the regions of interest for quantitative evaluation of radiopharmaceutical uptake in the navicular region (1), region of insertion of the DDFT (2) and toe region (3) and the wings (4 and 5) of the distal phalanx.

**Computed Tomography**

CT is ideally suited for cross-sectional analysis of complicated bone disease. In addition, osteolysis and osteogenesis can be detected well before any changes are perceived on conventional radiographs. Like for MRI, the horse must be anesthetized, but the resolution of cartilage, soft tissue contrast, and ability to detect medullary fluid are inferior to MRI. Nevertheless, CT has been used to standardize the optical density and width and depth of the DDFT in the foot as 106.8 HU, 35.05 ± 2.99 mm and 5.04 ± 0.66 mm, respectively. In another study, lesions of the DDFT were recorded in 15 of 78 horses with foot lameness examined using CT. The authors concluded that lesions of the DDFT could occur without concurrent abnormalities in the navicular bone. CT has been helpful in detecting subchondral bone erosions of the metacarpal and metatarsal bones. The surgical approach to a subchondral bone defect that requires grafting and is only visible on CT images, can be determined from a virtual reconstruction of the lesion on a 3D CT image. The preoperative tracing of the complicated spiralling pattern of sagittal fractures of the proximal phalanx or medial condylar fractures of the
metacarpus can be extremely useful in determining the position of implants to affect the strongest possible repair.44

Magnetic Resonance Imaging

MRI produces a grey-scale image of hydrogen protons in tissues, based on the measurable energy released when protons alter their orientation in a large magnetic field. Depending on the number and density of these protons and on the weighting of the particular MR sequence, different tissue types produce an MR signal of different intensity. In addition, tissue alterations caused by inflammation and tissue remodeling change the proton content and density, and, therefore, the MRI characteristics of a particular tissue. Consequently, MRI is particularly suited for evaluation of ‘occult’ injuries that remain undetected on radiographs, such as abnormalities of tendoligamentous soft tissues, bone marrow, and cartilage.

In the first author’s clinic, MRI is performed with the horse anesthetized and the limbs under scrutiny positioned in the isocentre of a short bore, flared end, high-field 1.5 Tesla Siemens Symphony magnet using a wrap-around extremity radiofrequency coil. Our examination protocol consists of sagittal, transverse, and dorsal dual echo sequences (2D T2 and proton density), sagittal and transverse short tau inversion recovery sequences (STIR), a three-dimensional (3D) T1 Flash (fast low angle shot) sequence with fat saturation in the transverse plane and a 3D T1 Fisp (fast imaging with steady precession) sequence in the dorsal plane. MRI has allowed us to make specific diagnoses in the distal portion of the limb and proximal aspect of the metacarpal/metatarsal region that could not have been made using other imaging techniques. MRI has thus radically changed the list of differential diagnoses of lameness caused by pain in the distal aspect of the limb. In our experience, MRI of the foot has been particularly useful in the recognition of abnormally high signal (fluid) in the DDFT, impar ligament, and collateral ligaments, abnormally high signal in the spongiosa of the navicular bone (i.e., ‘bone edema’), and abnormal signal in hyaline and fibrocartilage and subchondral bone. A breakdown of the MRI diagnosis of 199 horses with ‘occult’ foot lameness is shown in Table 1.45

<table>
<thead>
<tr>
<th>MRI LESION</th>
<th>% PRIMARY</th>
<th>% TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDFT</td>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>DDFT and Navicular Bone</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>CL DIP joint</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Navicular Bone</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>DSIL</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>DIP joint</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Multiple injuries</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Traumatic injury P2 or P3</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>SDSL</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 1. MRI findings in 199 horses with foot pain.
MRI of the fetlock region is less commonly performed than MR examination of the foot. Reasons for this difference include the relatively lower incidence of ‘occult’ lameness in this area, as the anatomy of the fetlock region is more readily accessible to physical examination and traditional imaging modalities are more likely to identify a lesion when compared to the foot. A breakdown of the MRI diagnosis of 21 horses with ‘occult’ fetlock lameness is shown in Table 2 (Schramme and Redding – unpublished data).

<table>
<thead>
<tr>
<th>MRI DIAGNOSIS (n=21)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmar metacarpal condylar sclerosis/necrosis</td>
<td>3</td>
</tr>
<tr>
<td>Intersesamoidean ligament desmitis</td>
<td>2</td>
</tr>
<tr>
<td>Oblique or straight distal sesamoidean ligament desmitis</td>
<td>3</td>
</tr>
<tr>
<td>Sesamoiditis/bone bruise</td>
<td>4</td>
</tr>
<tr>
<td>Subchondral cystic lesion sesamoid</td>
<td>2</td>
</tr>
<tr>
<td>OA</td>
<td>1</td>
</tr>
<tr>
<td>Subchondral bone lesion MC&lt;sub&gt;3&lt;/sub&gt; or P₁</td>
<td>5</td>
</tr>
<tr>
<td>Suspensory branch desmitis</td>
<td>2</td>
</tr>
<tr>
<td>Fetlock annular ligament tear</td>
<td>1</td>
</tr>
<tr>
<td>Proximal annular ligament desmitis</td>
<td>1</td>
</tr>
<tr>
<td>Collateral ligament desmitis</td>
<td>2</td>
</tr>
<tr>
<td>No obvious abnormalities</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2. MRI findings in 21 horses with fetlock pain. Several horses had simultaneous occurrence of 2 or more injuries.

**Conclusion**

The diagnosis of the site of pain causing lameness in the distal portion of the limb relies on the integration of the clinical evaluation, the response to regional analgesic techniques, and the information provided by the most appropriate imaging modality (or modalities). The condition that best fits the results of all 3 examinations is the most likely cause of the horse’s lameness, and treatment should be initiated accordingly. Yet, while new, previously unrecognized conditions are being identified by imaging modalities, such as MRI, we should realize that our knowledge of the causes of (distal limb) lameness remains incomplete.
References


