Correlation of magnetic resonance images with anatomic features of the equine tarsus

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Objective—To correlate anatomic features of the equine tarsus identified in plastinated sections with images obtained via magnetic resonance imaging (MRI).

Animals—4 horses.

Procedure—MRI (1.5-Tesla magnet) of the tarsus was performed on the pelvic limbs of 4 clinically normal horses following euthanasia. After imaging, tarsocrural joint spaces and vasculature were injected with colored latex. Sagittal and transverse images were acquired in proton density-weighted and T1-weighted sequences. Sections of the tarsi were plastinated to facilitate interpretation of MR images.

Results—Relevant anatomic structures were identified and labeled on the plastinated tissue slices and corresponding MR images. Results indicated high correlations between MRI findings and those of plastinated sections.

Conclusions and Clinical Relevance—The data obtained provided certain reference standards for normal anatomic structure sizes and positions in the equine tarsus. This information may aid future physiologic or clinical studies of this joint. (Am J Vet Res 2006;67:756–761)

Magnetic resonance imaging has proven valuable for diagnosis of a broad range of pathologic conditions in all parts of the body, especially in joint and musculoskeletal disorders. Recent literature provides descriptions of clinical findings regarding the distal portions of the limbs of horses obtained via high- and low-field MRI. The normal anatomic features of the carpal joint, phalangeal and metacarpal joint, tarsus, and foot have been demonstrated via MRI. Magnetic resonance imaging has been used in the diagnosis of interosseous tendon injuries, ossified cartilages, and navicular disease. The tarsus is affected by numerous pathologic processes involving the articular cartilage, subchondral bone, and soft tissues; these are common causes of chronic lameness in horses. Magnetic resonance imaging provides more information about pathologic changes in the feet of horses than any other imaging technique. Magnetic resonance imaging can identify lesions not apparent on radiographs or with ultrasonography and can define causes of lameness that can be localized only to a region of the limb. Magnetic resonance imaging is an invaluable diagnostic aid for the accurate diagnosis and treatment of lameness problems in horses.

The purpose of the study reported here was to correlate anatomic features of the equine tarsus identified in plastinated sections with images obtained via MRI.

Materials and Methods
Pelvic limbs were obtained from 4 purebred Spanish horses euthanized for reasons unrelated to any musculoskeletal disorder. Three horses were male, and 1 was female, and their ages were 3, 3, 4, and 6 years, respectively. The limbs were scanned within 2 hours of euthanasia, and oil markers were placed in the specimens prior to MRI to facilitate identification of the sections. After MRI, tarsi were sliced sagittally or transversely to aid in the evaluation of anatomic relationships of various structures of the tarsus.

Magnetic resonance imaging was performed by use of a scanner with a superconducting magnet operating at a field of 1.5 Tesla. The specimens were severed at the level of middle of the tibia and placed, with the tarsal and digital joints in extension, in a human extremity coil to obtain the images. Images were acquired by use of a spin-echo pulse sequence. Sagittal and transverse images were acquired in proton density-weighted images with the following settings: time of repetition, 1,360 milliseconds; echo time, 14 milliseconds (sagittal images) and 15 milliseconds (transversal images); echo number, 1; number of excitations, 1 (sagittal images) and 1.5 (transversal images); matrix size, 512 rows by 224 columns; and slice thickness, 6 mm. From 230 images, representative images of the tarsal joint at various levels that best correlated with the sagittal and transverse macroscopic slices were selected.

The arteries, veins, and synovial structures of the clipped and cleansed tarsi were injected with red, blue, and green latex, respectively, by use of a peristaltic pump. Arterial injection was carried out via the femoral or popliteal arteries. Injection was continued until red latex was present in the smaller arteries. After arterial injection, venous injection was performed via 1 of the 2 plantar digital veins, as distal as possible to avoid valve interference. The tarsocrural joint was injected via its plantar pouches (lateroplantar and medioplantar). After latex became hard, the tarsal specimens were frozen for 10 days at –80°C. The frozen limbs were sectioned either transversely or sagittally from the tibia to the metatarsus by use of a high-speed band saw with a 4- to 6-mm thickness. At least 20 sections were made from each specimen. The cut surfaces of each section were rinsed and numbered.

ABBREVIATIONS
MRI Magnetic resonance imaging

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before fixation. Photographs were obtained of both surfaces of each section before and after fixation. Sections were plastinated via a published technique. The plastinated slices were used to facilitate accurate interpretation of the anatomic structures.

**Results**

Representative anatomic structures were identified in the MR images and plastinated sections (Figures 1 and 2). The use of a superconducting, high-field magnet operating at 1.5 Tesla of intensity and pulse sequences of a spin echo in proton density resulted in excellent anatomic definition of the bony, articular, ligamentous, and tendinous structures of the equine tarsus (Table 1). The use of a human extremity coil permitted close apposition of the magnet field to the tarsus, which yielded good images of structures such as the synovial pouches of the tarsocrural joint (Figure 2). Synovial fluid had high signal intensity. Proton density-weighted images yielded excellent contrast between the low signal intensity of subchondral and cortical bone and the high signal intensity of trabecular bone and bone marrow (high fat-tissue content; Figures 2 and 3). Tendons and ligaments had low signal intensity (dark gray or black; Figures 1 and 4). Muscles had an intermediate signal (different levels of gray).

In sagittal images (Figures 1 and 2), there was excellent differentiation of the synovial fluid, synovial membrane, 2 opposing articular cartilages, and subchondral bone. Of special interest were the dorsomedial, lateroplantar, and medioplantar synovial pouches of the tarsocrural joint, which were delineated by high signal intensity. The sagittal section revealed that the lateroplantar and medioplantar synovial pouches were associated with the cranial aspect of the calcaneus and the caudal aspect of the coxale of the tibia. These pouches communicated with the synovial cavity at the level of the tibiotalar and talocalcaneal lateral ligaments. The medioplantar pouch was associated with the lateral digital flexor tendon, proximal to the sustentaculum of the calcaneus. The dorsomedial pouch communicated with the tarsocrural synovial cavity in the medial sagittal section (Figure 2). The distal extension of this pouch was limited by the medial branch of the tibialis cranialis tendon. The cranial tendon of the peroneus tertius muscle and the dorsal branch of the tibialis cranialis tendon formed the lateral limit of this pouch.

Details of the centrodistal joint were evident in the sagittal sections; the joint line between the central tarsal and third tarsal bones was located in the same transverse plane as the dorsal branch of the tibialis cranialis tendon, which is a palpable anatomic reference. At this level of the tarsus, the canalis tarsi, with important vessels to avoid during the approach to this joint, was also evident.

![Diagram of the equine tarsus](image-url)
The tendon sheaths of the long digital extensor and cranial tibial muscle and the calcaneal bursa of the superficial digital flexor muscle also had high signal intensity (Figure 1). The tarsocural joint capsule had low signal intensity (dark gray; Figures 1 and 2). The opposing articular cartilage layers appeared as a homogeneous structure with moderate-to-high signal intensity. In some areas of the sagittal image, it was not possible to distinguish between opposing articular cartilage layers and the line of synovial fluid. The semitransparent macroscopic slices allowed accurate verification of many anatomic structures in the magnetic resonance images. It was possible to identify different ligaments such as the interosseous tibiocalcaneal, centrodistotalometatarsal, long plantar, and tibiotalar ligaments. In addition, it was easy to identify many other structures such as the tarsal sinus and the tarsal canal.

In transverse images (Figures 3 and 4), there was good definition of the tarsal bones, especially the small tarsal bones. The malleolus of the tibia and collateral ligaments of the tarsocural joint had better definition in transverse MR images than in sagittal images. In the same way, other structures of the tarsus, such as tendons, intertarsal joints, and synovial pouches, were delineated. These sections gave much information about the extent of synovial pouches and their relationships with other structures, such as the collateral ligaments, joint capsule, talus, and calcaneus. It was possible to observe the communication between the laterolateral and mediolateral pouches and the synovial cavity of the tarsocural joint at the level of the talocalcaneal lateral ligament. The more superficial part of the laterolateral pouch was in contact with the caudal face of the lateral collateral ligament. The more superficial part of the mediolateral pouch (caudally) was close to the medial digital flexor tendon and sheath. The transverse section revealed the communication between the dorso-medial pouch and synovial cavity of the tarsocural joint. It was important to identify the dorsal relationship between this pouch and the medial saphenous vein and its branches.

Table 1—Signal intensities obtained via various MRI techniques in horses.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Synovial tissue</th>
<th>Cortical and subchondral bone</th>
<th>Trabecular bone</th>
<th>Tendons and ligaments</th>
<th>Muscle</th>
<th>Joint capsule</th>
<th>Articular cartilage</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-weighted</td>
<td>Gray</td>
<td>Black</td>
<td>White</td>
<td>Dark gray to black</td>
<td>Variable gray</td>
<td>Light gray</td>
<td>Dark gray to black</td>
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<tr>
<td>T2-weighted</td>
<td>White</td>
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<td>Gray</td>
<td>Dark gray</td>
<td>Gray</td>
<td>Black</td>
<td>Light gray</td>
</tr>
<tr>
<td>Proton density-weighted</td>
<td>White</td>
<td>Black</td>
<td>White</td>
<td>Dark gray</td>
<td>Variable gray</td>
<td>Black</td>
<td>Light gray</td>
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The distal transverse section (Figure 4) revealed the important relationship between the medial branch (cunean tendon) of the tibialis cranialis tendon and the first and second tarsal bone; the tendon crossed the medial collateral ligament before inserting in the first and second tarsal bone. In the same transverse plane, the perforating tarsal artery and vein in the tarsal canal, between the central tarsal and fourth tarsal bones, had high signal intensity. Transverse images revealed the relationship between the peroneus tertius, cranial tibial, and long digital extensor tendons and the different arteries and veins in the dorsal area of the tarsus (Figures 3 and 4). Relationships between the lateral digital extensor and medial digital flexor tendons and the lateral and medial collateral ligaments, respectively, were also evident.

Discussion
Usually, horses that are referred for MRI have lameness for which the cause is not revealed via radiography, ultrasonography, nuclear scintigraphy (bone scan), or computed tomography. Unlike radiography, which yields a 1-dimensional image of bone, MRI permits viewing the limb in 3 planes and many slices. It is also an excellent tool for viewing soft tissues such as tendons and ligaments. This allows the diagnostician to view all tissues of the limb from numerous angles to precisely locate the problem.

A previous MRI study of the equine tarsus used T1- and T2-weighted sequences. T1-weighted images are excellent for evaluating anatomic details of the periarticular structures and allow good identification of articular cartilage because its high signal intensity contrasts sharply with adjacent low-intensity subchondral bone. T2-weighted images provide better visualization of synovium than T1-weighted images, but the resolution and detail of the images are less than optimal for an anatomic study. T2-weighted images are best for revealing abnormalities in periarticular muscles and synovial fluid. Proton density-weighted images could be useful not only for anatomic evaluation but also for pathologic evaluation. The use of latex injection of vessels and synovial spaces allowed an accurate and exhaustive description of the images obtained, providing some clinical reference standards for the size and position of normal anatomic structures. The use of proton density-weighted images obtained with a 1.5-Tesla magnet allowed good identification of different structures of the equine tarsus, such as bones, joints, ligaments, and tendons. The use of a human extremity coil allowed close apposition to the equine tarsus and, consequently, a good signal. The proton density-weighted images do not depend on the time of repetition or echo time. A long time of repetition is necessary to reveal fluid as hyperintense; because of this, it is
possible to differentiate other synovial structures such as subtendinous bursae and synovial sheaths. It should be interesting to use this technique during in vivo examinations to decrease movement artifact. Previous studies of the equine tarsus that used 3 planes reveal that the sagittal and transverse planes provide the most complete visualization of most of the clinically important anatomic structures.

Knowledge of tissue intensities on proton density-weighted images is necessary for interpreting the scans. The high signal intensity of synovial fluid is similar to T2-weighted images and the opposite of T1-weighted images. The high signal intensity (brilliant white) of the synovial fluid in the dorsomedial, lateroplantar, and medioplantar pouches of the tarsocrural joint is of special interest because it will allow evaluation of the synovial fluid. The high signal intensity in the tarsal canal and in the gap between the first, second, third, and central tarsal bones is in agreement with a previous study, in which this area was identified as lines of communication between the distal intertarsal and the tarsometatarsal joints. Arthritic changes in this area most commonly affect the medial aspect, near the meeting of the third and central tarsal bones and the third metatarsal bone. Osteoarthritis of the distal intertarsal and tarsometatarsal joints is a common cause of performance-limiting lameness in the pelvic limbs of all types of equine athletes. Anti-inflammatory medications frequently allow horses to continue in training and performance. However, cartilage degeneration continues and may progress to fusion in some joints. This region is crossed by the medial branch of the tibialis tendon (cunean tendon), and this tendon is a useful reference point because it is palpable.

The intermediate signal intensity of muscles with proton density-weighted images is higher than with T2-weighted images but similar to T1-weighted images. The sagittal images allow excellent anatomic evaluation of the tarsocrural, intertarsal (talocalcaneal, calcaneoquartal, talocalcaneocentral, and centrodistal), and tarsometatarsal joints.

In proton density-weighted images, the opposing articular cartilage of the cochlea of the tibia and of the different tarsal bones cannot be differentiated from the synovial fluid. No synovial fluid was present between these articular cartilages because the signal intensity was lower than that of synovial fluid elsewhere in the same images. Both proton density- and T2-weighted images are adequate for detection of cartilage abnormalities with a sensitivity of approximately 73% to 87%. Articular cartilage has lower signal intensity than adjacent fluid, and subchondral bone is well visualized. Even in the absence of fluid, borders of the cartilage are readily visible. One of the best indicators of cartilage injury is indirect evidence in the form of subchondral...
bone injury (hyperintense signals). T2-weighted images reveal high signal intensity in injured subchondral bone associated with an increase in tissue water content because of edema or inflammation. In contrast, signal intensity in trabecular bone depends on its content of fat tissue. This is consistent with previous reports.1,5

Cadaver limbs are commonly used for anatomic studies with MRI.1,5 Signal intensities in the study reported here were similar to those previously reported5,6 for cadaver limbs. Vascular structures had high signal intensity, which is different from that recorded in live animals. Blood flow within vessels normally prevents good signal acquisition, and vascular structures of live animals are seen as areas of low signal intensity.8 Signal intensities of other tissues should be similar to in vivo imaging. If differences existed, they should not have affected image quality enough to alter appreciation of anatomic structures.

The highly detailed sectional images obtained with MRI can often reveal anatomic detail and pathologic changes that may not be detected with other common imaging techniques.1 For example, ultrasonography can be used to detect injury in the superficial or deep digital flexor tendons or the plantar ligament. However, in nondistended joints, the joint capsule is situated too closely to the underlying bone to be identified separately via ultrasonography;7,8 we were able to detect the joint capsule via MRI. Ultrasonography is less effective in deep areas of the tarsal joint and cannot detect pathologic changes such as synovial herniation or a narrow synovial fistula.11 The main disadvantage of an ultrasonographic tarsal study is the inability to penetrate bony structures, which yields images that are superficial to the bones of the tarsus. Arthrography has been used as a diagnostic modality procedure in the equine tarsus, but it is an invasive procedure and may cause an inflammatory response.16

Disadvantages of MRI include limited availability, high cost, and the need for anesthesia for use with high field-strength magnets. Low field-strength magnets are now marketed that, in theory, can obtain images in a standing, nonanesthetized horse, but the disadvantages are motion artifact and resultant poor image detail (spatial resolution). Image acquisition is not complicated, and many images can be obtained, but their analysis is time-consuming and requires experience based on comparison with cadaver studies of clinically normal horses and horses with pathologic abnormalities.3,7

Results of the present study indicate that MRI can enhance knowledge of the anatomic features of the equine tarsus. It may also help in the early diagnosis of problems that cannot be diagnosed by use of other means, such as osteoarthritis, osteochondrosis, tendonitis, desmitis, and traumatic intra-articular tarsal fractures.

a. Genesis-Sigma, General Electric Medical Systems, Special Diagnostic Service of San Roque Clinic, Las Palmas de Gran Canaria, Spain.

References