Imaging of the Distal Limb

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Imaging of the distal limb is a common occurrence due to a number of cases which have lameness localized to this region. Although the hoof wall creates limitations in imaging of the distal limb, many important structures proximal to the foot can be difficult to image due to location, superimposition of structures or the nature of the abnormality. Radiography has traditionally been the first imaging modality selected. However, many cases are complex involving osseous and soft tissue structures and therefore require multiple imaging modalities to make the most precise and complete diagnosis as possible.

Although digital radiography (DR) and computed radiography (CR) have much to offer in the way of convenience, they continue to have many of the limitations of standard film-screen radiography. Unfortunately, all radiographic techniques require a significant degree of osseous change to result in a detectable finding. By altering the image contrast, digital and computed radiography allow visualization of different structures on the same image. This process would have previously required additional radiographs. This has important implications on work flow and radiation exposure which are advantageous. We recognize that negative radiographic studies do not rule out osseous abnormalities. Negative radiographic findings or positive radiographic findings associated with soft tissue structures prompt further imaging studies to characterize potential lesions.

Computed tomography provides bone detail far superior to any of the other imaging modalities. Even with the addition of contrast to enhance visualization of soft tissue abnormalities, CT cannot compete with MRI for soft tissue detail. Computed tomography remains superior for evaluating bone margins, osseous abnormalities such as fractures, and bone density. In certain cases of osseous abnormalities such as subchondral bone cysts, debate remains as to the imaging modality of choice. Although CT may provide better osseous detail with regard to the cyst, clinically relevant findings such as peri-cystic fluid and abnormalities in the associated articular cartilage will be better delineated on MR images.

Nuclear scintigraphy provides vascular and soft tissue information. However, this information has a finite time window for acquisition and is therefore only applied to limited anatomic regions. Nuclear scintigraphy is often described as a sensitive but not specific imaging modality; it directs us to sites of osteoblastic activity without providing specific information about the cause of the activity. Areas of radiopharmaceutical uptake are used alone or in conjunction with other imaging modalities to infer clinical significance. Entheses or sclerosis found with other imaging modalities may have different degrees of clinical significance depending on the appearance when imaging
using nuclear scintigraphy. Although a direct correlation between radiopharmaceutical uptake and pain or lameness is not always present, this modality adds important information into the clinical picture that often factors into the treatment plan. Principles of scintigraphy and normal radiopharmaceutical uptake patterns must be known for proper image interpretation.\textsuperscript{1-3}

Ultrasound and MRI remain the optimal choices for soft tissue imaging. Ultrasound remains inexpensive and readily accessible compared to MRI. However, MRI provides unparalleled soft tissue detail. It is important to remember that ultrasound remains more sensitive for osseous margin changes, when compared to radiography and MRI. In contrast, MRI is superior to any other imaging modality for demonstrating fluid within bone. As with other modalities, a negative ultrasound study does not rule out abnormalities.

Ultrasound examination of the foot has been well described.\textsuperscript{4-5} This imaging modality is extremely operator dependent, and imaging of the distal limb is technically challenging. In addition, it is not possible to visualize all the soft tissue structures within in the foot. Structure visualization varies by case and it is dependent on the foot conformation, and frog shape and condition. The shape of the heel bulbs and foot conformation dictates the window for imaging the structures proximal to the navicular bone. Penetration of the sound beam and therefore image quality with transcutaneous examination is dependent on the condition of the frog. In dry climates soaking of the foot is required for transcutaneous examination. In very dry climate paring of the frog is required prior to soaking to allow the water to penetrate the frog. Mild depression of the frog with digital pressure is usually an indication that the sound beam can penetrate the frog well.

Techniques have been developed for imaging structures proximal and distal to the navicular bone including: deep digital flexor tendon, navicular bursa, collateral sesamoidean ligament, impar ligament. The proximal and distal margins of the navicular bone can be evaluated, the extent of which is partially dependent on the conformation of the foot. The proximal aspect of the collateral ligaments of the distal interphalangeal joint and associated bony attachments as well as the dorsal aspect of the joint can be evaluated. All structures should be evaluated in two imaging planes.

Examination of the deep digital flexor tendon includes evaluation of the tendon lobes which should be symmetrical in size and shape. The opposite limb should be used for comparison. Evaluation of the deep digital flexor tendon in the foot is limited by beam angle. The curvature of the tendon often prevents the sound beam from striking the tendon fibers at 90 degrees which creates the normal echogenic appearance present in the other areas, such as the pastern and metacarpus. Therefore assessment of the fiber pattern can be challenging and at times not possible. The mesotendon is echogenic regardless of beam angle, therefore changes in size, shape and margins in the deep digital flexor tendon are most easily detected. Normal tendon fibers proximal to the navicular bone are commonly dark gray to black, depending on gain settings. Mal-aligned fibers can often be identified in this region because they are echogenic in contrast to normal tendon fibers. This requires somewhat of a reverse thought process in regards to echogenicity.
compared with other regions. Normal tendon fibers are dark and therefore only mal-aligned fibers can be at 90 degrees to the sound beam and produce an echogenic pattern. Other causes of echogenic or hyperechogenic regions in the deep digital flexor tendon at this level include fibrosis and mineralization, the echogenicity of these tissue types is not dependent on beam angle. Severe fibrosis can result in complete shadowing, and therefore should not be ruled out based on that criterion. Identification of fluid in the deep digital flexor tendon without other abnormalities, such as size and margin changes, can be difficult or impossible to detect because it can have the same echogenicity as normal tendon fibers. The lobes of the deep digital flexor tendon may have to be evaluated individually in the transverse plane depending on their shape and the foot conformation. Large areas of edge artifact can result from the sound beam deflecting away from the curved margin of the tendon lobe. Changing the orientation of the probe and evaluating the lobes individually often decreases the impact of this artifact.

The collateral sesamoidean ligament and navicular bursa are easily imaged and abnormalities in anatomy and echogenicity can be well detected. The collateral sesamoidean ligament has a symmetrical shape, uniform echogenicity and well defined margins. Synovial proliferation in the proximal palmar recess of the distal interphalangeal joint can obscure the dorsal margin of the collateral sesamoidean ligament which on initial evaluation may cause the ligament to appear falsely enlarged. Close examination will usually allow detection of the true dorsal margin and allow assessment of the size of the ligament. Distention and synovial proliferation of the navicular bursa can be easily detected. However, determination of adhesions as opposed to synovial proliferation between structures such as the collateral sesamoidean ligament, navicular bursa, and deep digital flexor tendon is difficult or impossible. Abnormality on the dorsal margin of the deep digital flexor tendon can be an indication of adhesion formation; however, this criterion is not always reliable. Dynamic examination in this region has not proven helpful to confirm the presence of adhesions.

Transcuneal examination of the foot allows visualization of the deep digital flexor tendon, impar ligament and distal recess of the navicular bursa. Attenuation of the sound beam by the frog affects the image quality affecting the severity of the lesions which can be detected in this region. In contrast to examination of the deep digital flexor tendon proximal to the navicular bone, transcuneal examination often allows evaluation of fiber alignment and echogenicity. The fibers of the deep digital flexor tendon and impar ligament are often oriented such that the sound beam can strike them at 90 degrees producing a traditional echogenicity pattern. Following initial examination, minor paring of the frog can be used to improve the probe angle. If there is an extreme difference between the angle of the deep digital flexor tendon and the frog a stand-off pad can be used to allow proper orientation of the probe. The stand-off pad will cause additional attenuation of the sound beam further decreasing the image quality. Unfortunately, the window of visualization achieved with transcuneal examination is small and varies depending on foot conformation. Lesions which are not located close to midline often cannot be visualized. Bone margins are well visualized and entheses or bone resorption at the attachments of the deep digital flexor tendon and impar ligament can be demonstrated.
Evaluation of the deep digital flexor tendon at the level of the navicular bone is challenging. The extreme angle required to image the tendon yields the least information, especially in regard to fiber pattern, compared with more proximally or distally located exams. However, changes in size, shape and margins of certain severity can still be detected. Abnormalities, depending on location, in the navicular bone flexor surface can also be identified.

The proximal aspect of the collateral ligaments of the distal interphalangeal joint can be evaluated at the level of the coronary band. Evaluation of soft tissue and osseous abnormalities is possible. The collateral ligaments of the distal interphalangeal usually have a uniform echogenic pattern with smooth margins. It is important to note that the fibers at the origin may not all be oriented at the small angle. Fibers closer to the second phalanx, or in the axial portion of the ligament, can be at a more acute angle compared with more peripherally located fibers. These fibers require a different probe angle to create the normal echogenic appearance. Therefore it is not possible in all cases to image fibers at the same level with the same probe angle. Abnormalities should be identified in transverse and long axis images. The bone margin of the second phalanx should be smooth and uniformly echogenic at the origin of the collateral ligaments of the distal interphalangeal joint.

Although many structures in the foot can be visualized with ultrasound there are significant limitations when compared to MRI. However, continued correlative imaging will improve our technical skills as ultrasonographers. A common problem with ultrasound is many stages of lesions can appear the same on ultrasound images. Although this overlap exists with MRI it occurs less often. In addition, visualization of certain lesions will require MRI.

**Magnetic Resonance Imaging**

Magnetic resonance imaging has changed our understanding of lameness in the distal limb. It has revealed the many different injuries that were once categorized as “navicular syndrome”. It has facilitated targeted treatment and will likely result in the development of new treatments, both medical and surgical. This modality provides us the opportunity to identify and characterize soft tissue and osseous lesions like never before. These are the principles that should govern the development of protocols for this modality. Once a basic understanding of MR physics is in place, the next step is to understand the strengths and weakness of the different systems and sequences available. This knowledge will allow you to design a complete protocol that will properly utilize the different sequences improving identification of abnormalities and characterization of lesions. Although the general principles of MR physics apply to all systems, it is important to understand the specifics of the system you work with or refer cases to.

**MRI Sequences**
Major categories of sequences commonly used in MR imaging include fast spin echo (FSE), inversion recovery (IR), and gradient echo (GRE). Each type of MR sequence produces images acquired using a different method, thereby providing different information. The different methods of acquisition of these sequences have a specific impact on the appearance of the images in regard to detail, contrast and artifacts. Within the major categories of sequences there are additional parameters that are used to influence the tissue contrast of the images. Spin echo and gradient echo sequences have additional terms included in the sequence name that are indicative of these specific parameters used for image acquisition which have a direct impact on image contrast. Sequence designations such as “T1 GRE” means the images were produced by a T1-weighted gradient echo sequence and T2 FSE images were produced by a T2-weighed fast spin echo sequence. Additionally fast spin echo sequences can also be proton density, this term generally is not applied to gradient echo sequences. Although it is possible to adjust the parameters of a gradient echo sequence such that there would be contrast similar to this sequence. This is one major difference with MRI compared to other imaging modalities. The same tissue, for example fluid, can be white on one type of sequence and dark gray on another. This variation in appearance of the same tissue on difference sequences is a direct result of the parameters used for image acquisition. Although T1-weighted and T2-weighed images have some similarities whether they are produced using a fast spin echo technique or a gradient echo technique there are differences in contrast and resolution that are important to understand. The inherent qualities of MR imaging requires that the person evaluating the images understands the different sequences and knows the expected appearance of the tissues on the sequences in order to be able to accurately detect abnormalities.

Fast spin echo images are acquired mainly by using multiple radiofrequency pulses to affect the position of protons within the tissue creating a detectable signal. Spin echo sequences can be T1-weighted, T2-weighted, or proton density. Proton density and T1-weighted sequences will produce images with good anatomical detail, although proton density images usually have higher contrast when compared to T1-weighted images. The appearance of bone is similar on T1-weighted and proton density images. Fluid is dark gray (intermediate to low signal intensity) on T1-weighted images and light gray (intermediate signal intensity) on proton density images. In comparison, T2-weighted images have slightly less anatomic detail and higher contrast. Fluid is light gray to white (intermediate to high signal intensity) on T2-weighted images. Adipose tissue is usually light gray on T1-weighted and proton density images. It is light to dark gray on T2-weighted images, depending on image acquisition. Alterations can be made to a certain degree in the signal intensity of a tissue depending on how the images are acquired. On all sequences, without the presence of artifacts or abnormalities, cortical bone and tendons are black (low signal intensity). There is a range of MRI system settings that will produce variable signal intensities within specific sequence types. For example, on comparison of T1-weighted images from two different systems tissue signal intensities will likely vary.

Inversion recovery sequences are produced in a similar fashion to fast spin echo sequences except that there is an additional radiofrequency pulse at the beginning of the
sequence. This additional radiofrequency pulse is used to suppress the signal from adipose tissue. Suppression of the signal produces images with adipose tissue that appears black (low signal intensity). The image acquisition creates images that have the least amount of fine detail when compared to the other sequences. However, this sequence serves a specific purpose which makes the lack of anatomic detail acceptable. In musculoskeletal imaging, elimination of the bright signal from fat allows differentiation between fluid and fat in tissue such as trabecular bone. This allows diagnosis of fluid in bone which can be the result of traumatic contusion or edema as well as other causes. The short T1 inversion recovery (STIR) sequence is an example of this sequence type. The fluid attenuated inversion recovery (FLAIR) sequence is used in brain imaging to differentiate normal CSF from abnormal fluid.

There are additional methods to suppress the signal intensity from fat. A fat suppression technique can be combined with fast spin echo and gradient echo sequences to retain the image contrast of the original sequence while producing images with low signal intensity adipose tissue. These images are produced for the same purpose as inversion recovery sequence, to highlight fluid in tissue; however, they have higher resolution than inversion recovery images. This process requires excellent magnetic field homogeneity and is best done on high field systems.

Gradient echo sequences start with an initial radiofrequency pulse to manipulate protons, but then further alter the position of the protons by creating a gradient across the magnetic field. Gradient echo sequences can be either T1-weighted or T2*-weighted, which will determine the appearance of the imaged tissue. The T2*-weighting or effects produced with a gradient echo sequence is not synonymous with the T2-weighting produced using fast spin echo techniques. Gradient echo sequences are acquired in a different manner than spin echo sequences. The difference in acquisition creates images with low tissue contrast which are more susceptible to artifacts caused by magnetic field inhomogeneity. Gradient echo sequences acquire information in a volume which allows thin tissue slices and produces images with good anatomical detail that can be acquired in less time when compared with spin echo images.

When evaluating images it is important to take note of both the major sequence category used to produce the image (FSE, GRE or IR) and the specific parameters that were used to create the tissue contrast (T1-weighted, T2-weighted or proton density). Each of these factors can be used not only to have an expected appearance of the images, but also a perception of the strengths and weakness of the sequence and the prevalence of the artifacts.

Protocol Development Based on Lesion Identification and Characterization

Magnetic resonance imaging protocols should be based on the following major principles: identifying anatomy including size, shape and margins, identifying and characterizing pathologic change, and ruling out artifacts. The soft tissue and osseous detail achieved with MRI provides the most precise information about lesions. As we continue to learn more about lesion appearance on this modality we will improve our
ability to detect the fine details that will provide us with more information about the stage and nature of lesions. Therefore, we should select sequences and imaging planes creating a protocol that will facilitate this process while providing a reasonable examination time for the patient.

Traditionally a sequence is selected that is considered the anatomical reference. It allows identification of most of the structures in the imaged area and certain types of abnormalities. In addition, it is used to compare to other sequences that better highlight other types of abnormalities. Identification of anatomy requires good spatial and contrast resolution. A sequence with the highest spatial resolution and thinnest slices isn’t necessarily beneficial if it has poor contrast resolution. If structure margins can’t be identified from other surrounding tissue, then the spatial resolution of the sequence is no longer an advantage. When selecting a sequence as an anatomical reference it should be possible to see the size, shape and margins of most of the structures. For example, it should allow differentiation of fluid from synovial tissue and ligament margins from surrounding fat and subcutaneous tissue. Proton density and T1-weighed images have the highest resolution; however, the increased contrast of a proton density image allows better differentiation of structures. When comparing a T1-weighed image to a proton density image, it will be easier to identify the margins between synovial fluid and the surrounding joint capsule on the proton density image.

Another important component to protocol selection is artifact prevention and/or identification. Artifacts are an inherent part of MR imaging and not necessarily the result of system malfunction. Therefore they are present in every study, so it is important to recognize them for proper interpretation of a study. What are the most common artifacts which could affect image interpretation? What sequences would be required to correctly identify these findings as artifacts and avoid misinterpretation? For the artifacts commonly found in MR imaging it is important to know the cause and method to determine the presence of an artifact versus a real finding. These principles are then applied to protocol development. Partial volume averaging (PVA) which was described in “New Technologies and Advances for Equine Practitioners” is a common artifact that directly affects image interpretation in every MR study (Fig. 1). The two most effective ways to decrease PVA is decreasing slice thickness and proper slice position during study planning.6 In general, decreased slice thickness will decrease partial volume averaging and increase image quality or more specifically spatial resolution. Producing images using thinner slices results in increased examination time. In addition, less information is acquired for each slice from the tissues to produce the image. Therefore, there comes a point where decreasing slice thickness will actually decrease image quality because there is not enough information to create an image. Assessing slice thickness is important. In general, the thinnest slice that yields visibly improved image quality without excessive examination time should be used. The degree of improvement in image quality should equate to the potential risks of increased examination time. As previously stated in the description of PVA, small and low contrast lesions are most susceptible to this artifact. Magic angle artifact results in increased signal intensity in ligaments and tendon with fi-
Fig. 1. STIR sagittal (A and D) and transverse (B and C) images of a foot. There is increased signal intensity in the dorsal aspect of the navicular bone on the transverse image (B, block arrow) which is not present on the sagittal image (A). This finding is the result of partial volume averaging. This transverse image (B) is located at the proximal aspect of the navicular bone and includes fluid in the proximal palmar recess of the distal interphalangeal joint which is adjacent to the proximal cortex of the navicular bone. Comparison of this image with other imaging planes and sequences would be required to identify this finding as an artifact. This horse has abnormal fluid in the dorsal medial aspect of the second phalanx (B and C, arrowheads) and in the palmar aspect of the navicular bone (C, line arrow) which could also be identified on sagittal images (A, line arrow and D, arrowhead).
bers oriented at approximately 55 degrees to the main magnetic field. Although the effect is greatest at 55 degrees a signal increase can be present between 45 and 65 degrees. This artifact occurs in sequences with a short TE, less than 37ms, and is most commonly seen on proton density and T1-weighted images. T2*-weighted gradient echo and STIR images can be produced with a TE less than 37ms and would therefore be susceptible to this artifact. The artifact does not occur on sequences with a long TE. Identifying the increased signal intensity as an artifact as opposed to an injury requires comparison evaluation of the structure on a sequence with a long TE, such as a T2 FSE. Other examples include susceptibility artifact on gradient echo sequences which are best identified by comparison to fast spin echo sequences. Chemical shift artifact, in which the location of the artifact can be moved out of the area of interest by changing sequence parameters, or it is less apparent on fat suppressed sequences. Incorporating a method for ruling out the common MR artifacts by sequence selection is an important part of protocol development.

Proper slice positioning is critical in any system, but especially with low field systems. The increased slice thickness that must be used with low field systems produces images which are more susceptible to PVA. These studies require more detailed slice positioning to decrease the effects of PVA as much as possible. Image slices that are positioned in true sagittal, transverse and frontal planes to structures of interest decrease the amount of partial volume averaging that occurs in these structures. Small structures, such as the impar ligament, require extra attention to detail when planning studies. The imaging planes and slice positioning for a protocol should be based on structures of interest which are most commonly injured. Images of these structures should be obtained in multiple planes. Confirmation of lesions in multiple planes is required to rule out partial volume averaging. Obviously images cannot be positioned properly for every structure in the foot because of the different orientation of the structures. However, it is important to prioritize for the most commonly injured structures while still allowing adequate imaging for less common or unusual injuries. Often the limb becomes rotated or angled when positioned in the magnet. When this occurs it is not always possible to position slices correctly for all the areas of anatomy. For examples slices positioned properly at the level of the third phalanx can be obliated at the level of the second phalanx due to the rotation or angle of the limb. It is important for the person planning the study to have a priority list of structures in order to position the images. In addition, use of consistent anatomical landmarks will facilitate study planning. It often becomes necessary to compromise on the slice positioning to try and accommodate most of the structure correctly. This will increase PVA in certain structures, but is unavoidable in many cases.

Accurately characterizing a lesion requires comparison of images from the anatomic reference sequence with other sequences. A combination of sequences must be chosen that maximize the ability to identify and characterize lesions. T2-weighted, STIR and/or fat-suppressed sequences are used for this process. Each sequence has advantages and disadvantages, but they complement each other and together with the anatomic reference sequence provide the most information about lesions. Lesions that contain fluid or are associated with changes in fluid content or distribution will be most easily detected on STIR and fat-suppressed images. These sequences will best demonstrate fluid in bone

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and soft tissue. STIR images have the lowest resolution. Small lesions with minimal fluid may not be well demonstrated on STIR images, especially if the lesion is divided between two slices and may then not be visible due to partial volume averaging. Suppression of the signal from adipose tissue may sometimes obscure the borders of structures that are surrounded by subcutaneous tissue containing a large amount of adipose tissue. Suppression of the signal from the adipose tissue creates a similar signal intensity between the structure of interest and the surrounding tissue obscuring margins. The extent of the similarity between the two signal intensities is dependent on the degree of suppression of the adipose tissue signal which can vary with sequence parameters. As an example the defect resulting from a margin tear on the axial margin of the collateral ligament of the distal interphalangeal (DIP) joint at the level of the second phalanx is often filled with fluid due to the adjacent proximity of the DIP joint. This will be very apparent on STIR images, with focal thinning of the ligament and a defect occupied by high signal intensity. A similar lesion on the abaxial margin of the same ligament may not contain fluid. This lesion may be less evident on a STIR image and more evident on a sequence that has increased contrast between the ligament and the surrounding tissue, such as a T2-weighted image.

An important consideration when evaluating areas of abnormal signal intensity is comparison known structures. Signal intensity corresponding to fluid, fluid mixed with tissue, normal tendon and normal ligament will be available for comparison. As an example increased signal intensity on STIR images in structures such as tendons and ligaments should always be compared with an area of pure fluid to try to assess the degree of fluid associated with the lesion. Signal intensity which is not as bright as pure fluid can indicate the presence of tissue, cells or other substances mixed with fluid which can have implications for characterization of the lesion.

T2-weighted images have higher resolution than STIR images and higher signal intensity of adipose tissue. The degree of difference between the sequences based on resolution and contrast is dependent on the system used and parameters. Although high signal intensity fat is a disadvantage for identifying fluid, it provides contrast between structures. The sequence can often be acquired such that there is a difference in signal intensity between fat and fluid will retain the contrast between fat and other soft tissue structures. These settings maximize the advantages of T2-weighted sequence and minimize the disadvantages. Increased signal intensity in soft tissue structures on T2-weighted images can be an indication of more severe, advanced injury than on T1-weighted or proton density images alone. This can differ from information obtained on STIR images because although the injury may be more severe may not contain fluid and therefore may not be evident on STIR images. This also allows differentiation from magic angle which would be most evident on T1 or PD.

STIR and T2-weighted images provide different types of information which can be beneficial to lesion characterization. The MR system and sequence parameters used will determine how much difference in resolution is present between a T2-weighted image and a STIR image, thereby determining the potential benefit of having both types of sequences. The type and stage of lesion will dictate the sequence which will best
demonstrate the lesion. Degeneration, inflammation, granulation tissue and fibrosis have many different stages and therefore a range of appearances on MR images. The signal intensity will change based on fluid and cellular content as well as the nature of the injury. Use of these sequences in combination with the anatomic reference sequence will provide the most information about a lesion.

Continued education on the science of MRI is important to further our knowledge and develop protocols that maximize the information gained from this modality. The science of MRI is rapidly changing, and seemingly recent literature may not always be applicable or what is being currently used in the clinical setting in human medicine. This is important to note because searching the human literature can be misleading without a concurrent awareness of the present applications in human medicine.

The current protocol for the distal limb at Colorado State University includes proton density FSE, T2-weighed FSE and STIR images. Sagittal, frontal and transverse images are acquired. Slices are positioned relative to the deep digital flexor tendon, navicular bone, impar ligament, collateral ligaments of the distal interphalangeal joint and the articular surfaces of the distal and proximal interphalangeal joints (Fig 1-6). This protocol is based on consultation with a human radiologist who specializes in orthopaedic MR imaging and with comparison to other sequences. This protocol has produced excellent image quality and provided the most information about the osseous and soft tissue structures in the distal limb with a reasonable examination time.

**Conclusion**

Magnetic resonance imaging is a valuable modality allowing diagnosis of soft tissue injuries that were not able to be identified previously. The normal appearance of structures with age and exercise must be determined for image interpretation and disease diagnosis. Establishing which sequences are best for identifying specific diseases will advance this process. Identification of pathologic change and knowledge of the clinical significance of findings is necessary for an accurate diagnosis. Collaboration will expedite this process and benefit clinicians and patients. Specific diagnosis of soft tissue and osseous injuries characterized using MRI will allow appropriate and targeted treatment, rehabilitation, and monitoring.

**References**


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**Fig. 2.** Sagittal images (A) are planned using transverse (B) and frontal (C and D) images. Important landmarks include the sagittal ridge of the navicular bone on transverse images and the axis of the limb on frontal and transverse images. The white rectangles indicate the orientation of slices on the transverse and frontal images used to produce sagittal images.
Fig. 3. Frontal (A and B) images are planned using sagittal (C) and transverse (D) images. Important landmarks include the margins of the deep digital flexor tendon, the flexor surface of the navicular bone and margins of the interphalangeal joints on sagittal and transverse images. Often these structures have different alignment, therefore a compromise must be made in slice positioning. White rectangles indicate orientation of slices on the sagittal and transverse images used to produce frontal images. Using this orientation visualization of the articular cartilage is best in the distal aspect joint compared with other areas due to decreased partial volume averaging (B).
Fig. 4. Transverse (A) images are planned using sagittal (B) and frontal (C and D) images. The sagittal images are used to angle the slice perpendicular to the deep digital flexor tendon and navicular bone. This is done to decrease the amount of partial volume averaging and provide true transverse plane images to these important structures. The frontal images should be used to angle in the medial to lateral direction. This directly impacts the degree of symmetry in the transverse images and is essential for proper slice positioning. Important landmarks on the frontal images are the proximal and distal margins of the navicular bone and the articular margins of the distal interphalangeal joint. The angle and position of the origin and insertion of the collateral ligaments may also be considered. However, they may be oriented differently than the navicular bone and articular margins. If a sequence specific to the collateral ligament will be performed the collateral ligament landmarks should not be heavily relied upon in this set of transverse images.
Fig. 5. Transverse images oriented to the collateral ligaments of the distal interphalangeal joint (A) can be performed using sagittal (B and D) and frontal (C) images. The collateral ligaments can be identified on a parasagittal image for proper slice positioning (B). The frontal (C) images are used to correct for rotation of the limb and create a symmetrical transverse image (A). This plane usually provides a long axis image of the deep digital flexor tendon and impar ligament distal to the navicular bone (D and E). The degree of correspondence between these planes (long axis images of deep digital flexor tendon and transverse images of the collateral ligaments) is partially dependent of the position of the third phalanx relative to second phalanx.
Fig. 6. Images oriented along the long axis of the collateral ligaments of the distal interphalangeal joint (A) can be performed using sagittal (B and D) and transverse (C) images. The collateral ligaments can be identified on a parasagittal image for proper slice positioning. The transverse images are used to correct for rotation of the limb and create a symmetrical frontal image (C). These images usually provide transverse plane images of the deep digital flexor tendon and impar ligament distal to the navicular bone (A and D). In addition, visualization of the articular cartilage in the palmar aspect of the distal interphalangeal joint with decreased partial volume averaging relative to previously shown frontal images is also possible (A).