CHAPTER **46**

CT AND MRI DIAGNOSTIC IMAGING GUIDELINES FOR FOOT AND ANKLE PATHOLOGY

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Diagnostic imaging of the lower extremity has become a popular and useful adjunct to the practice of clinical podiatric medicine. The variety of conditions that can be image-enhanced is rapidly growing, as our experience with Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) broadens. Although in certain clinical scenarios these studies approach the diagnostic reliability of a tissue biopsy, they are not to be depended upon as a replacement for physical examination and plain-film radiography, which are still the mainstays in clinical diagnosis.

Special imaging studies are useless if the clinician who is ordering the test cannot interpret the exam, since it is the clinician alone who must make the diagnosis. A radiologist can render an opinion based upon what is observed on a film, but without the advent of a clear and detailed history and physical examination, that opinion is limited and should be correlated to the patient's condition.

In order to appreciate the benefits that CT and MRI offer, it is imperative to understand the basis on which they function, which is cross-sectional anatomy. Regardless of whether these studies are enhancing bone mineral content or fluid density values, it is the ability to reliably identify normal anatomic structures that enables us to distinguish pathologic anatomy. Although it is a labor-intensive process to learn to read cross-sectional anatomical films, it is also a burden of duty to our patients. In addition to being able to identify anatomic structures on a film, one must also be critical of the quality and technique of the study. Uniformity of testing techniques adds reliability and reproducibility to this process. Much in the same way that we follow uniform standards for obtaining plain-film radiographs, so should standards exist for special studies such as CT and MRI.

TECHNIQUE-DEPENDENT VARIABLES

Technique-dependent variables must be understood and controlled in order to obtain a useful study which will provide accurate and reliable information necessary to distinguish anatomic structures. Control of these variables is important in the process of performing the exam, and will determine the usefulness of the information gained so that an accurate interpretation of the study can be made. The technique-dependent variables that will be discussed include the area of study/interest, angle of study, image spacing, and image thickness/width.

Area of Interest

A common error in examining the lower extremity is to focus on too large of an anatomic region, thereby limiting the amount of useful information that is gained in the specific area of anatomic interest. Too often the sampling area exceeds the actual area of concern. Due to time constraints and the desire to achieve an acceptable study that will not need to be repeated, the technician will often sample a large area of the lower extremity. It is not uncommon to order a study of the ankle which includes digits, foot, ankle, and leg (Fig. 1, Section A). In sampling a large area, it is necessary to limit the number of images to a reasonable amount, due to both time and cost constraints. However, in order to cover a large anatomic area with a limited number of images, it is necessary to separate the images further apart, thereby limiting the number of images that are obtained in the desired area of interest. To compensate for spacing the images (slices) further apart, thicker slices are obtained to limit the amount of unsampled tissue, thereby ensuring that the largest possible volume of tissue is sampled. By limiting the sample area to the specific area of interest, more information (more images) can be provided for a higher image quality (Fig. 1, Section B).

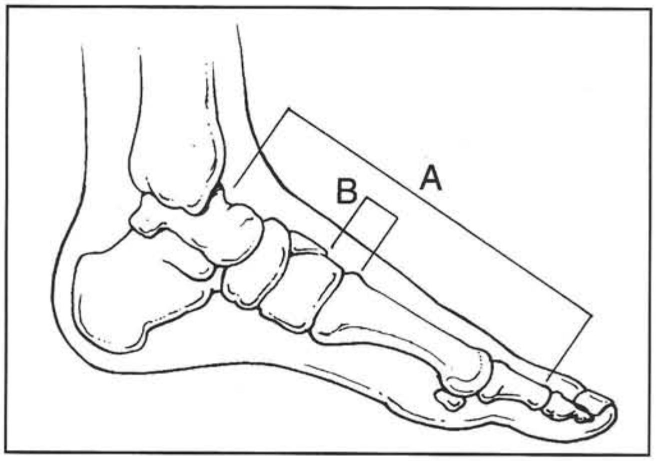

Figure 1. Section A demonstrates a large area of interest, while Section B demonstrates a narrow area of interest, in this case the Lisfranc joint.

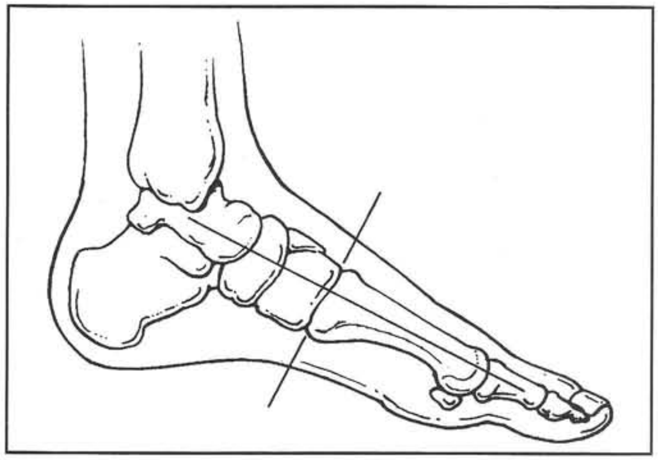

Figure 2. The optimal angle of study is parallel to the joint(s) and perpendicular to the long axis of the bones.

Angle of Study

The angle at which images are obtained with relation to the axis of the foot influences image quality and reproducibility, and in turn the ability to accurately describe anatomic structures and landmarks. Likewise, the ability to identify anatomic structures influences the ability to differentiate normal from abnormal structures or features, and hence the ability to identify a pathologic process. In the learning curve that accompanies the process of reading diagnostic films, it is imperative to have uniformity between similar studies so that the examiner can relate familiarity based on experience. A lack of uniformity when comparing similar studies forces the examiner to continuously re-orient, based on known anatomic landmarks, and then interpret the image in an attempt to identify pathology.

This concept of uniformity is readily apparent when comparing plain-film radiographs that are taken at random, unfamiliar angles. The appearance of the image will be distorted, not beyond what is physically being viewed, but beyond our mental image of what we are used to seeing on a standard view which is taken at a uniformly prescribed angle. Any significant deviation from the standard view angle will look unfamiliar, and force the examiner to interpret the quality of the study while trying to interpret the film for pathology.

In general, images should be obtained in a direction which is perpendicular to the long axis of the bone, which is also usually parallel to the surrounding joints. In the foot, this applies to the majority of the bones and joints which the podiatrist is typically interested in examining. In viewing a lateral radiograph of a foot, it is apparent that there is a straight-line orientation of the bones, from the talus to the metatarsal heads. Likewise, the joint lines that connect each of these bones are generally perpendicular to this long axis orientation (Fig. 2). This true axial image of the foot is uniformly reproducible.

In addition, a view which is oriented 90° degrees to this true axial would be parallel to the long axis of the bones, and similarly perpendicular to the joint lines (coronal view). When considering the talus, the long axis "true axial" image is also perpendicular to the talocalcaneal joint, which satisfies the need for imaging of this joint structure. Slight angular deviation from this true axial image will impart distortion on the images, and cross joints obliquely, thereby reducing the uniformity and usefulness of the study.

Obtaining the correct axial angle of study can be influenced by either positioning the patient, altering the angle of the gantry (tube head), or both. A lateral scout film is used to ensure the proper angle of the machine in relation to the foot, both of which can be altered to achieve the desired angle.

When the angle of the study is not exactly perpendicular to the long axis of a bone, there is elongation distortion imparted upon the image. Elongation distortion occurs in the direction to which the image is angulated with respect to the long axis of the bone. Assuming that the foot is otherwise positioned transversely perpendicular to the angle of the study, and there is sagittal plane angulation off of the perpendicular, the images will

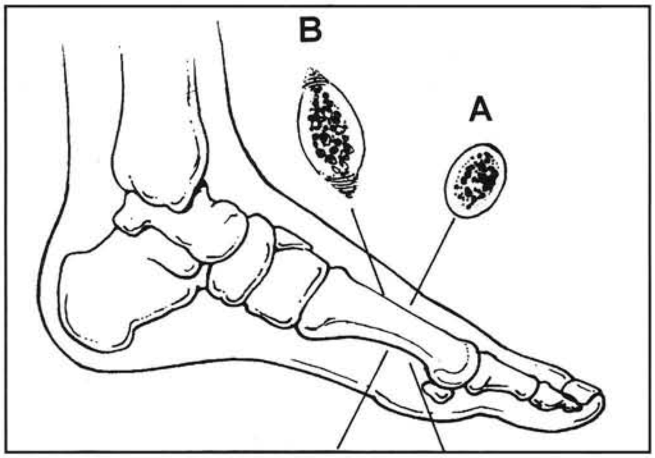

Figure 3. A demonstrates a correct angle of study through the first metatarsal, with no apparent distortion. B demonstrates an oblique angle of study, with elongation distortion and skived dorsal and plantar cortices of the first metatarsal.

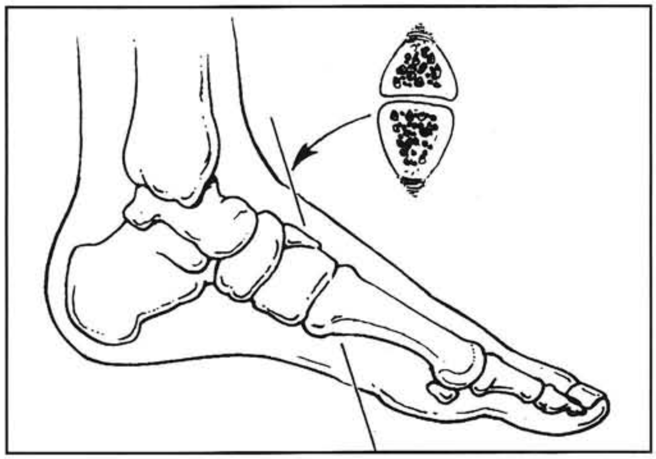

Figure 4. This diagram demonstrates the oblique crossing of a joint, with elongation distortion, along with variable bone densities in the same image.

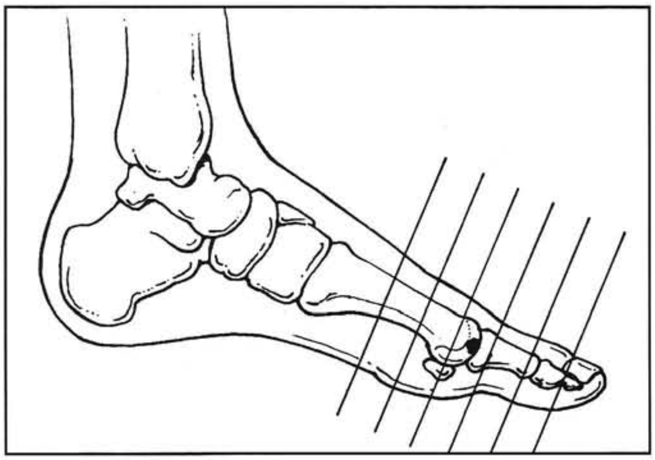

Figure 5. In this diagram of an osteochondral defect of the first metatarsal head, wide spacing of the images fails to cross the zone of pathology.

appear "stretched" from dorsal to plantar, while maintaining an accurate dimension from medial to lateral (Fig. 3). The dorsal and plantar surfaces of the bones will also appear less distinct and out-of-focus (fuzzy) since these surfaces are cut at an angle (skived) to the surface of the bone.

In addition to elongation distortion, sagittal plane angulation will lead to the oblique crossing of joints. When an image crosses a joint line obliquely, there is often difficulty in differentiating structures on either side of the joint line. Therefore, it may be difficult to differentiate an oblique cut through a joint from a pathologic process, such as a fracture or dislocation. In addition, an oblique cut through the foot will cross different anatomic regions, such that one may be viewing the diaphyseal cortex and empty medullary canal of a metatarsal on the same image that crosses a joint and demonstrates a cancellous midfoot bone, all of which have distinctly different bony characteristics on the same image (Fig. 4). Again, the quality of the study is being assessed and interpreted, in addition to the pathologic process, which reduces the amount of useful information that can be obtained. Maintaining a perpendicular angular orientation will reduce elongation distortion, avoid the oblique crossing of joints, and provide uniformity of tissue type, all of which will aid in clearly identifying normal anatomy and distinguishing a pathologic process.

Image Spacing

As previously discussed, the area of study must be localized to the specific area of interest in order to efficiently gain the most information. A large area of study requires spacing of the images apart from one another in order to limit the number of images. However, when spacing the images apart, the thicker images could potentially skip visualization of an area of pathology.

For example, a plain-film radiograph may demonstrate a small area of pathology, such as an osteochondral lesion, which fails to be visualized on a CT or MRI film (Fig. 5). Instead of providing more information to aid in the diagnosis or direct the treatment plan, an imaging film skips the area of pathology due to over-spacing of the images. This would actually detract from the diagnostic process by casting doubt on the diagnosis itself. Therefore, close spacing of the images reduces the chance of missing or skipping pathology.

Image spacing is set by the technician at the time of the study. Image spacing is measured in millimeters from the center of one image to the center of the next image, or measured "on center." It is possible to space images such that there is no space between the images, and in this case the images are "stacked" upon one another. Stacking of images ensures that all tissues within the study are sampled, thereby eliminating the chance of missing or skipping pathology. Likewise, each image corresponds to the adjacent images with no spaces that are left unsampled.

Depending on the size of the area to be studied, it may not be practical to stack images (no space between the images) due to the number of images required to complete the study. In most instances, there is a reasonable compromise made to ensure adequate tissue sampling without skipping too large of an area.

Image Thickness

The thickness of the image refers to how wide of an area is sampled within each slice, which is measured in millimeters. With a wide sampling slice, more volume or space is sampled with each image. A thin slice, on the other hand, samples a smaller volume or space of tissue. The thickness of the sampled image has implications which will affect the clarity of the image and its usefulness in making a diagnosis.

When sampling a thick slice of tissue (10 mm width), a large volume of tissue is contained within the width of the sample. A thin slice (1 mm width) samples a much narrower volume of tissue. A thick slice samples a wide volume of tissue, and thereby averages the densities of all of the tissues within its margins. This averaging of densities relates directly to image clarity, in that a thick image slice will have less definition of clarity as compared to a thin slice, which samples a much narrower volume of tissue. The thickness of the slice will determine the contrast available to differentiate close anatomic structures.

As an example, a thick slice which spans the width of a joint will have a poorer image quality due to the averaging of the densities of the tissues which are contained within its borders. A thick slice through a joint will average the densities of metaphyseal bone, subchondral bone plate, articular cartilage, synovial fluid, articular cartilage, subchondral bone plate, and metaphyseal bone. A thin slice, on the other hand, will pass through less tissue, and may only average one or two of these adjacent tissue densities. In short, image clarity and definition will be enhanced by providing a thin slice of tissue.

Imaging of the lower extremity often requires distinguishing anatomic structures that are in close proximity to one another. The many small and close structures in the region of the midfoot or rearfoot require accurate visualization to distinguish bony outlines and bordering joints. If one is interested in examining the extent of an arthritic process or determining if a bony coalition is present, slice thickness will influence the ability to do so. If a thick slice is obtained through the area of interest, it may be impossible to distinguish one bone from another, as averaging will cause the bony outlines to be obscured, and two bones which are actually separated may appear as one bony structure. A thin slice, on the other hand, is more likely to accurately demonstrate bone and joint contours and cortical outlines.

NOMENCLATURE

Image thickness is denoted in "millimeters in thickness" while image spacing is denoted in "millimeters on center." When referring to the type of study performed, the first number represents the image thickness, while the second number represents the distance between the images, measured on center. A study which has 10 mm thick slices which are 20 mm on center is referred to as a "10 X 20." In this instance, there is a gap of 10 mm which is not being sampled between the images (Fig. 6A). A study which has 10 mm thick slices which are 10 mm on center is referred to as a "10 X 10." This study represents stacked images with no gap between the images (Fig. 6B). A study which has 2 mm thick slices that are 3 mm on center is referred to as a "2 X 3." There is a 1 mm gap between the images (Fig. 6C). A "1 X 1" study has 1 mm thick slices which are 1 mm on center (stacked images). It is also possible to overlap the images. A "3 X 2" study has 3 mm thick slices which are 2 mm on center, which overlaps the images by 1 mm. This type of study is not necessary to perform, however, this technique will enhance the reconstruction of other images that are unable to be obtained by a first generation study (sagittal plane CT).

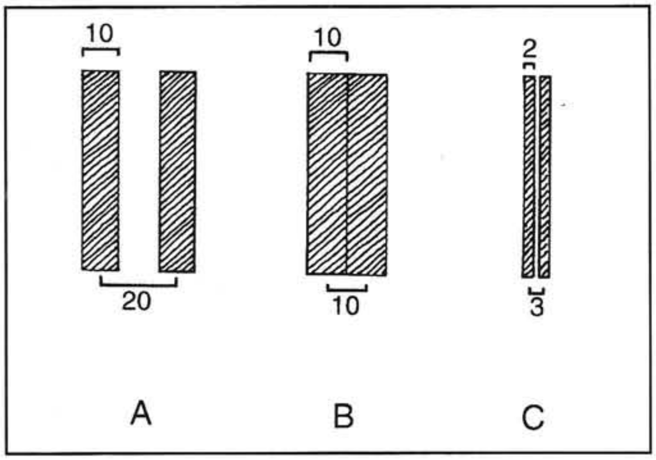

Figure 6. A demonstrates a "10 X 20" study with 10 mm of spacing between the images. B demonstrates a "10 X 10" study, with the images stacked upon one another, and no gap between the images. C demonstrates a "2 X 3" study, with a 1 mm gap between the images.

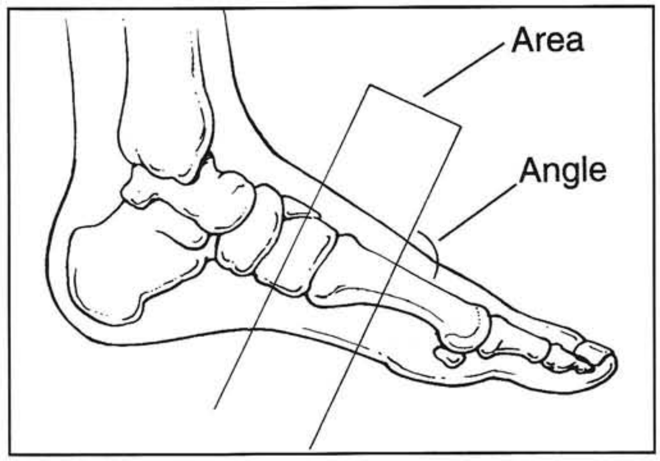

Figure 7. This diagram is sent with the patient's orders, demonstrating the angle of study, area of interest, and the slice thickness and spacing ("2 X 2").

HOW TO ORDER A STUDY

In order to ensure that an accurate, reliable, and useful exam be performed, the ordering physician should clearly outline the desired parameters of the study. This should include the area of interest, the angle of the study, the slice thickness (width), and image spacing distance.

Depending on the area of interest within the lower extremity and the suspected pathology, one can vary these parameters to meet the needs of the study. The area of interest must be highlighted to ensure that most of the images are contained within. It is advisable to include one-half of each bone to either side of the joint that is to be studied. For example, if the navicular bone is to be studied, one should include the proximal one-half of the adjacent cuneiform and the distal one-half of the adjacent talus. Within the foot, the study should always be performed parallel to the joint line and perpendicular to the long axis of the bone(s). As a general guideline, a study which has 2 mm thick slices 3 mm on center ("2 X 3") will provide good image quality with clarity of joint spaces. It is not unreasonable to request a "2 X 2" study or a "1 X 1" study if there is a very specific area of pathology that needs to be characterized, such as an osteochondritis dissecans lesion or a fracture non-union. However, in order to prevent over-sampling, one should clearly define the narrow area of interest.

To avoid technical errors in interpretation of a requested order, it is advisable to send a diagram along with the orders which depicts the desired study. This should include a visually clear outline of the previously mentioned parameters: area of interest, angle of study, and image thickness and spacing (Fig. 7). This will eliminate any possible misunderstanding between the ordering physician and the technologist who is performing the exam, prevent the need for repeat exams, and maximize the amount of useful information obtained in order to accurately diagnose a pathologic process.