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Operative Techniques in
Orthopaedics

Postoperative Imaging of Osteochondral Lesions of the Ankle

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Radiographic evaluation of chondral repair is an important component of postoperative care. Imaging can confirm normal postoperative appearance, objectively evaluate progression of healing, and provide early identification of postoperative complications. This article briefly discusses the techniques of chondral repair as they relate to postoperative imaging, imaging techniques to evaluate chondral repair, and the normal and abnormal appearances of tibiotalar chondral repair. We concentrate on high-resolution magnetic resonance imaging, the mainstay of chondral imaging.
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Introduction

As technology has advanced in surgical techniques of chondral repair or rejuvenation, so has the imaging of chondral lesions. It is no longer sufficient to identify an osteochondral fracture on radiograph: the radiologist is now responsible for identifying subtle symptomatic chondral abrasions or flaps that might be amenable to surgical intervention and for objectively evaluating the success of that intervention. Imaging should be able to describe the degree of chondral damage in an arthritic ankle and is on the cusp of being able to use ultrastructural techniques to see if chondral damage is imminent, even before there is any morphologic fibrillation.

As in the knee, surgery is reserved for treatment rather than diagnosis. However, the characteristics of chondral injury in the ankle and the appearance of repair cartilage differ between the knee and the ankle. The details of the differences are still being elucidated. Because the ankle is a more congruent, compact joint than the knee, the forces are different. This appears to affect the microenvironment of the joint. Because ankle cartilage is thinner than that in the knee, imaging it is more difficult. It is only with newer higher field strength magnetic resonance imaging (MRI) machines that thorough evaluation is possible. Ankle cartilage has not been studied to the extent that knee cartilage has been. Few longitudinal studies of the normal appearance of repair cartilage currently exist.[1]

This article introduces the imaging techniques, with a focus on MRI, for evaluating chondral damage and examines the postoperative appearance of ankle cartilage after the techniques described.

Imaging Techniques

Starting in 1895 with the x-ray, imaging has evolved. Radiographs developed correlates in fluoroscopy, tomography, and now computed tomography (CT), all of which can be enhanced by injecting a contrast agent into the ankle to look indirectly at the articular surfaces. Indeed, CT arthrography is the highest resolution modality. However, CT arthrography is invasive and only evaluates the chondral surface. It is rarely used in clinical practice and will not be discussed further.

We can now also image the articular surfaces with ultrasound. Although transcutaneous ultrasound has limited access to the cartilage in the ankle because of the overlying bone, the addition of an arthroscope can overcome this problem. Optical coherence tomography is a technique like ultrasound that is incorporated into an arthroscope. Obviously, the invasiveness of the study limits use to the intraoperative setting.

Nuclear medicine studies (the injection into the blood of a radioisotope that goes to bone based on how actively it is remodeling) such as bone scans and sodium (Na) fluoride positron emission tomography scans have been used preoperatively to evaluate stability of osteochondral lesions (OCLs).[2]

Because of its ability to visualize cartilage directly, MRI is the technique of choice to evaluate cartilage repair techniques. The

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higher the field strength of the magnet, the more detailed chondral evaluation can be, but the greater the artifact that will be produced by instrumentation. Typical clinical MRI units are 1.5 or 3 T. Stronger units, such as 7 T, are currently used mostly for research.[3] Lower field strength units, 0.6-1 T, can be used to image cartilage but not to evaluate ultrastructural characteristics. When looking at articular cartilage, 0.2- to 0.5-T units should be avoided.

Most clinical MRI use morphologic imaging to evaluate for chondral injury and other associated pathologies that relate to osteochondral abnormalities (ligament injuries, osteophytes, effusion or synovitis, bone loss, subchondral cysts, bone loss, and reactive bone marrow signal abnormalities). This type of image gives a semiquantitative evaluation in that it measures the size of chondral defects.

The pulse sequences (specific parameters set on the MRI units) that can be used to image morphology of cartilage vary. Centers have their own biases, but typically 3 general types of sequences are employed to look at cartilage directly. They include fast spin echo intermediate echo time sequences (often called proton density), that same sequence with fat suppression (to remove fat from the image), and a fat-suppressed (spoiled) gradient echo sequence. Because cartilage is so thin, imaging should be generally performed at a relatively high resolution to give good spatial differentiation.

Regardless of the sequence used, normal cartilage has a uniform thickness over the talar dome and tibial plafond. Normal cartilage demonstrates a stratified gray scale appearance on a proton density sequence, decreased signal intensity closer to the subchondral plate with progressively increasing signal intensity toward the articular surface (Fig. 1). This is because of increasing T2 values of cartilage toward its surface (stated later).

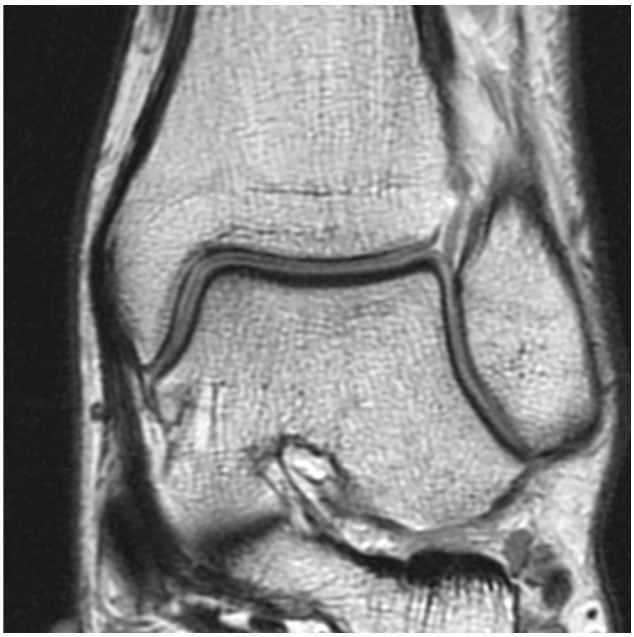

Figure 1 Normal articular cartilage. This coronal proton density image demonstrates normal articular cartilage in the tibiotalar joint. Note the uniform thickness of the cartilage over the talar dome and tibial plafond. The cartilage demonstrates signal stratification: darker toward the subchondral plate and lighter toward the articular surface.

There are a number of types of ultrastructural (also called compositional or biochemical) imaging. These include finding values of T2, T2*, and T1ρ; diffusion-weighted imaging (DWI); delayed gadolinium-enhanced MRI of cartilage (dGEMRIC); chemical exchange saturation transfer (CEST); and Na imaging. Each of these techniques has advantages and disadvantages. They are typically added as additional sequences beyond routine morphologic imaging, often for research purposes. Their utility is still being assessed for routine use. Conceptually, ultrastructural abnormality should precede morphologic abnormality so that if, for example, an ankle is unstable, ultrastructural imaging theoretically would predict the progression to cartilage loss (presumably from repeated injuries). Additionally, ultrastructural imaging can provide a reproducible and objective measure of success after chondral intervention and follow the progress of repaired cartilage.

For chondral repair, postoperative imaging can be enhanced with ultrastructural imaging. Morphologic imaging can detect filling of the chondral defect; however, subsequently one has to use other techniques to evaluate ultrastructural healing. Longitudinal studies of chondral healing have been performed in the knee. It turns out, however, that the knee behaves differently from the ankle, so more work using longitudinal studies of cartilage repair needs to be done to definitively establish normal progression of disease and repair in the ankle.

Types of Ultrastructural Imaging

Delayed Gadolinium-Enhanced MRI of Cartilage

This technique is an indirect measure of glycosaminoglycans (GAGs) using the inverse relation between the presence of negatively charged GAGs and negatively charged gadolinium (injected intravenously the gadolinium diffuses into the joint). Abnormal cartilage (depleted of GAGs) will have more gadolinium and thus, because of the characteristics of gadolinium, will have a shorter T1 (a measureable tissue parameter). Thus, a T1 map of the joint surface will have lower values in regions of abnormal cartilage.

T1 rotating (ρ) also measures GAG content. It obtains T1 values in a rotating field (B1) created by a special spin-lock radiofrequency pulse.

Na Imaging

Because of relatively low concentrations of Na in tissues compared with water, higher field strength (3 or 7 T) magnets are required for this technique as are special Na (as opposed to water) coils. Na imaging is another technique for quantifying GAG content. Normal cartilage has higher concentrations of Na than damaged cartilage.

Chemical Exchange Saturation Transfer

CEST is a relatively new technique for evaluating GAG content. Unlike Na imaging, it needs no additional hardware nor, as in dGEMRIC, does it require intravenous gadolinium