Sports Tips & Tricks: 5 Tips for MRI Evaluation of the Shoulder and Knee

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Introduction

While the history and physical exam provide the bulk of clinical information needed to make a diagnosis in orthopedic sports medicine, advanced imaging techniques such as magnetic resonance imaging (MRI) are increasingly used as diagnostic tools and for surgical planning. Radiology reads are typically readily available, but it is imperative for the orthopedic surgeon to be able to self-interpret MRIs with confidence. The following tips provide a guide for the review of MRI images of common sports injuries of the knee and shoulder. It is not meant to serve as a comprehensive report of pathology but rather a framework for the review of MRI images.

Tip #1 Learn the Vocabulary

MRI is an advanced imaging technique that uses magnets and radiofrequency coils to create three-dimensional representations of relevant anatomy.[1] While the basic science behind this process is interesting to some, it is not needed to properly interpret the MRI. There are a few key terms that are useful to understand. The field strength refers to the strength of the magnet used and is a property of the machine. Higher powered magnets, such as 1.5 tesla (T) and 3T, provide better resolution and are higher quality. The signal to noise ratio (SNR) is also a measure of quality and varies with the different pulse sequence settings set by the MRI technician. Factors influencing SNR include scan time, resolution, and slice thickness. High signal to noise gives a clearer representation of the anatomy.

Tip #2 Understand the Sequences

Different pulse sequences can be used to identify different tissues (Table 1).[1-3] These are settings that are altered by the MRI technician during the MRI scan. T1-weighted images have the highest SNR and are good for detecting anatomy. With T1-weighted images, fat and gadolinium are bright, while water and collagen are dark. T2-weighted images have the lowest SNR but are better at detecting fluid and edema, making them useful for identifying pathology. Fat remains bright and collagen remains dark in T2-weighted images, while water appears bright. Because we are typically looking for fluid/edema in locations where it might not normally be in musculoskeletal imaging, we usually want to suppress the fat brightness to show only fluid. In T2 weighted-images with fat suppression (T2 FATSAT), fat appears dark due to the purposeful suppression, while keeping the signals of the other structures in T2-weighted images the same. Proton density-weighted (PD) images have an intermediate SNR, which maintains the anatomic detail but limits the tissue contrast. Fat is typically suppressed with this type of sequence, and it is used to evaluate fibrocartilage as collagen appears dark and water bright. The final common MRI sequence used in sports medicine is short T1 inversion recovery (STIR) imaging. STIR imaging is similar to T2 FATSAT imaging in regard to the signal of fat, collagen and water. The amount of time it takes to obtain is much shorter than the typical T2 FATSAT, but the quality is not as strong. A basic understanding of the pulse sequences available can assist in the evaluation of various anatomy and pathology.

Table 1. Characteristics of MRI Pulse Sequences

	T1	T2	T2(FATSAT)	PD	STIR
Fat	Bright	Bright	Dark	Suppressed	Dark
Collagen	Dark	Dark	Dark	Dark	Dark
Water	Dark	Bright	Bright	Bright	Bright
Signal/noise	High	Low	Low	Intermediate	Low
Ideal Use	Anatomy		Pathology	Cartilage, ACL	

T1, T1-weighted, T2, T2-weighted, FATSAT, fat saturated; PD, proton density; STIR, short T1 inversion recovery, ACL, anterior cruciate ligament

Tip #3 Determine the Proper Plane

Orthogonal views are essential in the interpretation of images. Certain planes are more helpful than others depending on the joint or region of interest. In general, it is best to stay orthogonal to the structure of interest. For example, in the knee one would assess axial, sagittal, and coronal cuts, which are naturally in line with the joint. For the shoulder, which sits at approximately 30-degree angle due to the plane of the scapula, one would assess the axial, sagittal oblique, and coronal oblique. These oblique views are in line with the axis of the scapular plane and allow for better visualization of key structures.

Tip #4 Consistency is Key

While there are many different ways to approach reading an MRI, the most important factor is consistency. One surgeon may read an MRI "left to right," while another surgeon reads "out to in." There is not one universally agreed upon strategy as the best approach. However, each surgeon should read every MRI with the same approach every single time. This consistency is the best approach to ensure that all structures are appropriately assessed. There are six main groups of structures that should be assessed on every MRI: ligaments/tendons, meniscus/labrum, articular cartilage, bone, fat, and muscle.

Tip #5 Practice Makes Perfect

It is estimated that to become an expert, one must spend over 10,000 hours practicing a skill.[4] It takes time to hone MRI reading skills. For each patient with suspected pathology, systematically approaching the MRI scan will ensure that nothing is missed and provide the surgeon with another repetition. Even when the diagnosis is known, it can be helpful to approach the MRI as if the clinical correlation was unavailable, in order to practice identifying proper sequences and planes to assess both normal anatomy and pathology.

Evaluating an MRI of the Knee

Ligaments/Tendons

When assessing knee injuries, the anterior cruciate ligament (ACL) is one of the most commonly injured ligaments. MRIs are able to accurately detect up to 95% of acute ACL disruptions.[2] Ligaments will generally appear dark with all MRI sequences. The most useful MRI sequence to use to assess the ACL is the proton density-weighted images. The primary plane used to evaluate the ACL is the sagittal plane (Figure 1), although the axial and coronal planes are helpful in assessing the femoral attachment.[2] The PCL is best evaluated on the T2-weighted sagittal images, while the collateral ligaments are best evaluated on the T2-weighted coronal images. The best sequence to evaluate for pathology of the quadriceps tendon is the T2-weighted sagittal and coronal image.

Figure 1. PD sagittal view of an intact ACL.

Meniscus

The meniscus will appear dark in all pulse sequences and will look triangular in cross-section. The PD-weighted image is the best, followed by T2-weighted imaging in assessing for a meniscal tear. The primary planes used to evaluate for a meniscal tear is the sagittal plane and coronal planes (Figure 2). A common pitfall is to misidentify the intermeniscal ligament anteriorly or the meniscofemoral ligaments posteriorly as tears, when in fact they are normal anatomy. Scrolling through multiple cuts and tracing these structures to their anatomic footprints will prevent this mistake.

Articular Cartilage

Cartilage will appear gray (intermediate in signal intensity) on T2 and PD-weighted imaging. These sequences are the best to utilize when assessing for cartilage defects because of the contrast between joint fluid and cartilage.[1] T1-weighted imaging is not a good sequence for evaluating cartilage, because the appearance of water/joint fluid often mirrors the appearance of the cartilage itself. Cartilage defects of the femur or tibia are best visualized on the sagittal and coronal planes, while patellar defects are best seen on the axial plane.

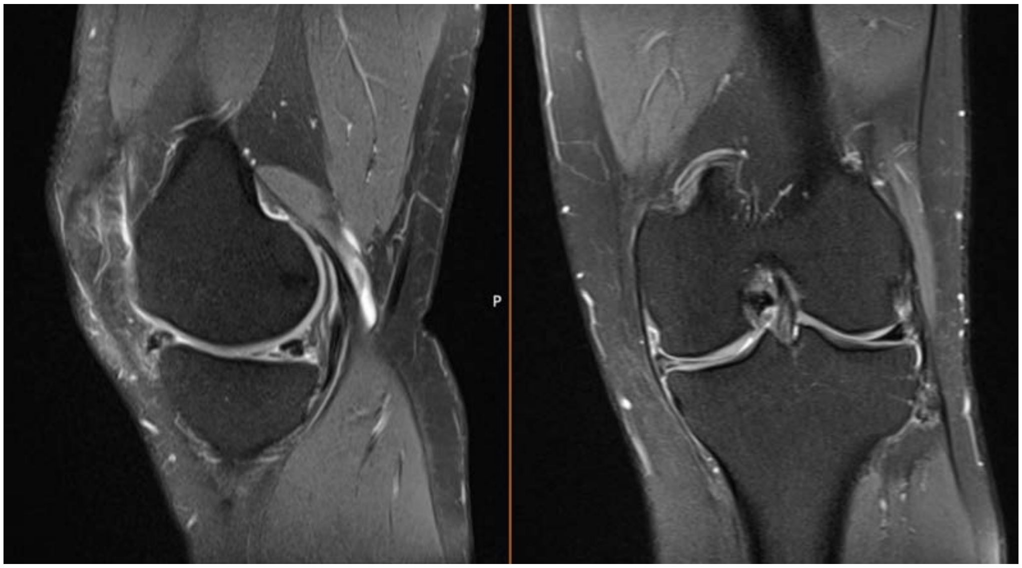

Figure 2. PD sagittal and coronal views of a patient with a medial meniscus tear.

Bone/Fat

Cortical bone is made of mostly calcium (hydroxyapatite) and collagen type I, giving it a characteristically dark appearance in all sequences. However, cancellous bone can appear similar to that of fat since marrow is composed of mostly fat. Thus, marrow will appear bright on T1-weighted images and dark on T2 5FATSAT. Bone marrow edema will appear bright and be contrasted with the dark bone marrow in the fluid-sensitive T2 FATSAT. Bone marrow edema seen in sports-related injuries is typically secondary to trauma and in conjunction with ligament injuries, and is helpful in identifying areas of injury. Sagittal, coronal, and axial planes will need to be assessed when evaluating for bone marrow edema or an occult fracture, and any abnormalities should be present in at least two views to confirm diagnosis.

Muscle

Muscles demonstrate intermediate signal intensity on all pulse sequences and therefore serve as a relative comparison for signal intensity of adjacent structures. T2-weighted images and STIR images highlight muscle edema and fluid collections. T1-weighted images are useful in assessing muscle atrophy, intramuscular hematoma, and distinguishing subacute blood from edema.[1]

Evaluating an MRI of the Shoulder

Ligaments/Tendons

The rotator cuff tendons, being made of mostly collagen type 1, will appear dark on all pulse sequences. The supraspinatus and infraspinatus are best evaluated on the T2 FATSAT or T2-weighted coronal and sagittal oblique planes, while the subscapularis is best evaluated on the T2 FATSAT or T2-weighted axial and sagittal oblique planes. Tendinopathy is depicted as intermediate signal intensity within the substance of the tendon on T2-weighted images. It is important to remember that these findings will also correlate with age-appropriate changes and patients might be asymptomatic.[3] A tear of the tendon will appear as bright fluid within the expected location of the tendon on T2-weighted images (Figure 3).

Labrum

The labrum, again being a mostly collagenous structure, will appear dark in all pulse sequences and appears triangular in cross-section with a smooth transition with confluent glenoid cartilage. Evaluation of the superior labrum is best on T2-weighted coronal oblique images, but axial planes are also helpful. The anterior and posterior labrum are best evaluated on T2-weighted axial images, while coronal oblique planes

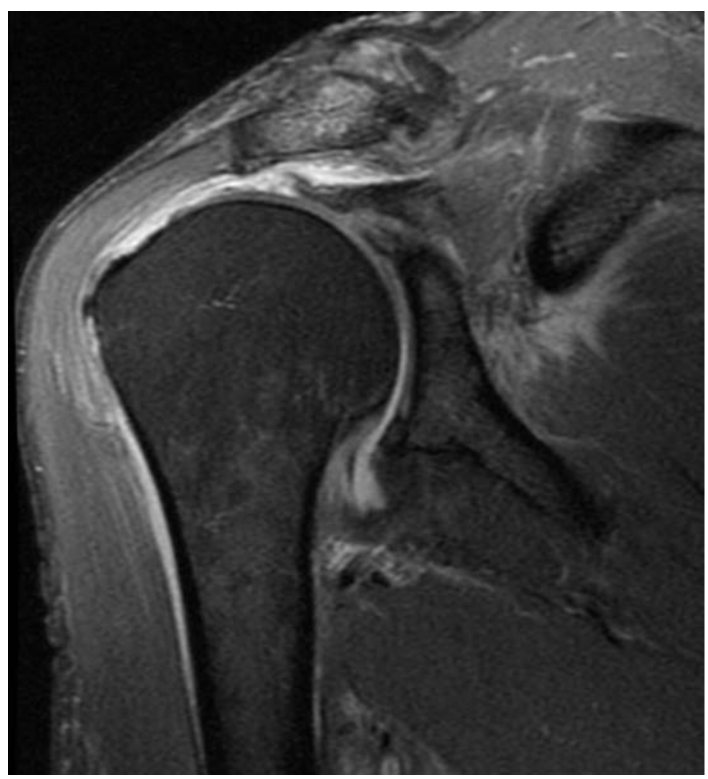

Figure 3. Coronal oblique view of a patient with a large supraspinatus tear.

are complimentary. The use of MR arthrogram has proved to be very helpful in detecting labral pathology, increasing sensitivities and specificities to 91-93%.[3]

Articular Cartilage

Similar to the knee, cartilage in the shoulder will appear as a thin gray uniform layer and have a smooth transition with the confluent labrum. Cartilage defects are best assessed with T2 FATSAT images in the coronal oblique and axial planes and with T1-weighted axial images with MR arthrogram.

Bone/Fat

Bone and fat have a consistent uniform signal and have a similar signal intensity on pulse sequences. They will appear bright on T1, T2, and PD weighted images. They require T2 FATSAT imaging to appear dark.

Muscle

As mentioned before, muscles serve as a relative comparison for signal intensity of adjacent structures. Muscles demonstrate intermediate signal intensity on all pulse sequences. Muscle edema and fluid are best evaluated on T2-weighted images and STIR, while intramuscular hematomas are best assessed with T1-weighted images. Fatty atrophy of the muscles will appear as high signal intensity streaks within the muscle and is best evaluated on T1-weighted sagittal images.

Conclusion

It is important for orthopedic surgeons to be able to self-interpret MRIs. This can be accomplished in five easy steps. Learning the vocabulary, understanding the sequences available, and determining the planes of interest for a given pathology provide a framework for the evaluation. Sticking to a systematic approach and continuous practice and experience will lead to more confident evaluation of MRI.

References

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