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Long-Term Results of Orthopedic Implants

MRI OF THE MUSCULOSKELETAL SYSTEM

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The potential of magnetic resonance imaging (MRI) in the evaluation of the musculoskeletal system was recognized in early clinical trials.[1] Although still relatively new and not yet developed to its full potential, MRI has already made a profound impact on the evaluation and management of many musculoskeletal disorders.[2,3]

Advantageous features of MRI include excellent depiction of bone marrow, high contrast discrimination of soft tissues, and the ability to directly image in any plane, including oblique. Disadvantages of MRI include a long scan time and poor definition of soft tissue calcification. Because MRI examinations are expensive and imaging systems are limited in number, this technique should be used only when it can be expected to provide information that is unavailable from less expensive, noninvasive means, and when the results of the examination may significantly alter patient management.

Findings in MR images may be nonspecific, and often, malignancy, trauma, and infection may appear similar in MR images.[4] Examinations should therefore be performed and interpreted with the full knowledge of findings of other imaging examinations, especially plain radiographs. Because MRI examinations yield the most information when they are tailored to a specific clinical problem, communication between the referring physician and the radiologist is essential. This will assure that appropriate imaging techniques will be used, and maximum diagnostic information may be obtained from any given examination.

Following a brief introduction to the principles of MR imaging, this article focuses on MRI of large joints (the hip, knee, and shoulder). The common forms of pathology for which MRI is now considered to be the imaging modality of choice are discussed.

BASIC PRINCIPLES OF MRI

Conventional radiography utilizes ionizing radiation in the form of x-rays. MRI, on the other hand, utilizes a strong magnetic field and superimposed radiofrequency (RF) pulses to form images.

When a nucleus contains either unpaired protons, neutrons, or both, it has angular momentum. This property provides the basis for MRI. Because of its abundance in the human body, hydrogen is used for clinical MRI. Within the MR magnet, the hydrogen atoms are aligned with the magnetic field. An RF pulse is then superimposed on the magnetic field, and the atoms are flipped onto their side. As the RF pulse is turned off, the atoms realign with the magnetic field. The energy they give off as they realign is the MR signal.

Although the appearance of osseous and soft tissues in MR images is influenced by several different factors, the most important determinants are the scanning technique and the pulse sequence chosen for the examination. Spin-echo (SE) imaging is the most frequently used technique, and is the only technique that will be discussed in this chapter. The combination of spin echo T1- and T2-weighted imaging will answer essentially all important clinical questions with respect to musculoskeletal pathology.

An image is considered to be T1- or T2-

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Fig 1: Bilateral osteonecrosis of the hips. Coronal T1-weighted (A) and T2-weighted (B) images. Abnormal intermediate signal intensity is present in the femoral heads bilaterally. That portion which remains low signal intensity probably represents saponified fat.

Fig 1A.

Fig 1B.

weighted according to the repetition time and echo time used for image acquisition. The repetition time (TR) is the time between RF pulses, and the echo time (TE) is the time between the application of the RF pulse and recording the signal. T1-weighted images (short TR and short TE, eg, SE 400/20) provide optimal anatomic detail, and are ideal for imaging bone marrow. T2-weighted images (long TR and long TE, eg, SE 2000/80) are often needed to demonstrate soft tissue pathology. The combination of T1- and T2-weighted imaging facilitates differentiation of tissue types.

When tissue is white in MR images, it is said to have a high signal intensity. Fat, including fatty bone marrow, is very high signal intensity in T1-weighted images, and will appear high to intermediate signal intensity in T2-weighted images (depending on the field strength of the magnet used for imaging). Tissues which are black in MR images are considered to be a signal void. Cortical bone, for example, is black with both T1- and T2-weighted imaging. Normal muscle is intermediate signal intensity in T1-weighted images, and intermediate to low signal intensity in T2-weighted images. Most soft tissue and bony pathology will be intermediate signal intensity in T1-weighted images and high signal intensity in T2-weighted images. As stated above, this finding is nonspecific, and tumor, trauma, and infection may have a similar MR appearance.

The Hip

MRI is now considered by most authorities to be the most accurate method for the early detection of osteonecrosis of the femoral head.[5-8] The MR appearance of osteonecrosis is subject to some variability. In all cases, however, the abnormality is characterized in T1-weighted images by a marked decrease in the normally high intensity signal of the femoral head bone marrow which remains, at least in part, low signal intensity in T2-weighted images (Fig 1). The changes may appear as a ring or band-like area of diminished signal, or a homogeneous or inhomogeneous focal region of diminished signal in the subarticular femoral head.

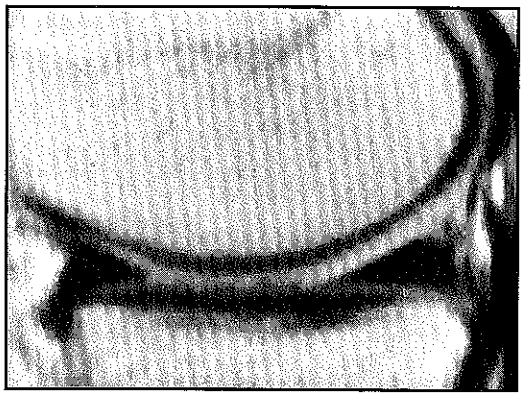
The reasons for the diminished signal have not yet been satisfactorily explained, nor have the pathophysiologic mechanisms behind the various MRI changes been proved. As with all imaging studies, MRI reflects gross morphologic changes rather than cellular physiology. Also, osteonecrosis is a dynamic process, with areas of varying signal intensity reflecting a spectrum from cell edema to cell death, as well as the host's attempt to revascularize and repair.

Pathologically, areas of low signal intensity in both T1- and T2-weighted images are associated with saponified bone marrow and cellular debris (necrosis).[9,10] Areas that are low to intermediate signal intensity in T1-weighted images and high signal intensity in T2-weighted images appear to represent either marrow edema or fibrovascular repair tissue. Mummified fat—cells that have lost their nuclei but whose cell walls remain intact—probably appears normal in MR images. A normal MR scan cannot, therefore, exclude early osteonecrosis.

The Knee

In the evaluation of internal derangement of the knee, MRI is rapidly replacing arthrography, and is being used as a screening examination prior to arthroscopy. High-resolution, thin-section, multiplanar images are capable of depicting the important soft-tissue structures of the knee joint, including the menisci and cruciate ligaments.[11-16] Most significant pathology can be evaluated with thin section or interleaved sagittal T1- and T2-weighted images. Coronal images are needed for the evaluation of the collateral ligaments, and may confirm the presence or absence of meniscal pathology. Axial imaging is generally best suited for the evaluation of the patellofemoral joint.

Fig 2: Normal meniscus. Sagittal T1-weighted image. The anterior and posterior horns are sharp triangles which are a homogeneous signal void.



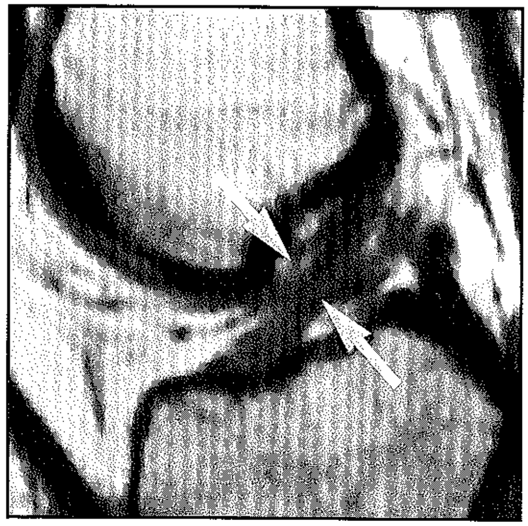
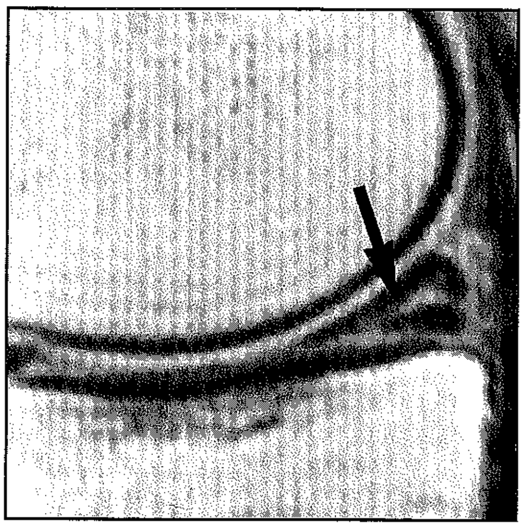


Fig 4: Normal ACL. Sagittal T1-weighted image. The normal ACL is a continuous band of low to intermediate signal intensity (arrows).

Fig 3: Meniscus tear. Sagittal T1-weighted image. The tear is evident as a band of high signal intensity which extends to the meniscal surface (arrow).



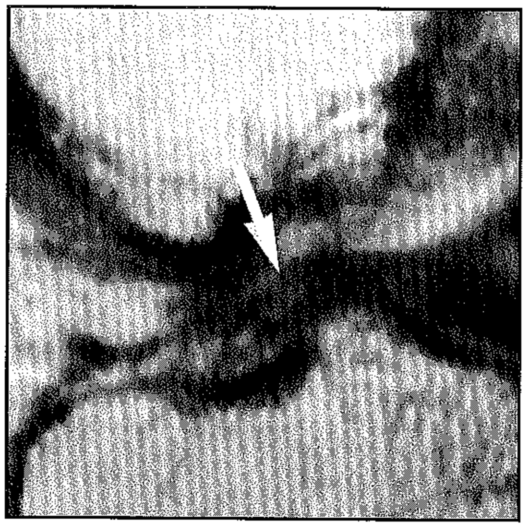


Fig 5: ACL tear. Sagittal T1-weighted image. Only remnant fibers of the ligament can be identified (arrow), and these take an abnormal horizontal course.

The normal meniscus appears as a homogeneous signal void in MR images (Fig 2). The anterior and posterior horns should appear as well-defined triangles on sagittal images. For the detection of meniscal pathology, one needs to evaluate internal meniscal signal characteristics, meniscal size, and meniscal contour. Several grading systems have been proposed to define intrameniscal signal changes. If a grading system is used, it is important that the referring physician and the radiologist understand which system is used, as well as the clinical significance of such a designation. In most instances, it is sufficient to simply describe findings as either normal, tear doubtful, tear possible, tear probable, or definite tear.

A meniscus that is absent or abnormally small may be the result of meniscal degeneration, avulsion, or prior meniscectomy. An abnormally large meniscus which extends across the weight bearing surface of the knee reflects a discoid meniscus. An ill-defined focus of signal or a band that does not extent to the surface may represent either degenerative changes or an intrasubstance tear. These menisci will generally appear normal at arthroscopy. A frank meniscal tear is evident as a line or band of increased signal intensity which extends to a meniscal surface (Fig 3).

The normal anterior cruciate ligament (ACL) is a fan-shaped structure which shows intermediate to low signal intensity in T1-weighted images (Fig 4). If torn, the ACL may be absent, disrupted, or may follow an abnormal course through the joint (Fig 5). Abnormal high signal intensity fluid may be seen within the ligament in T2-weighted images.[14] The normal posterior cruciate ligament (PCL) is a homogeneous signal void (Fig 6). A

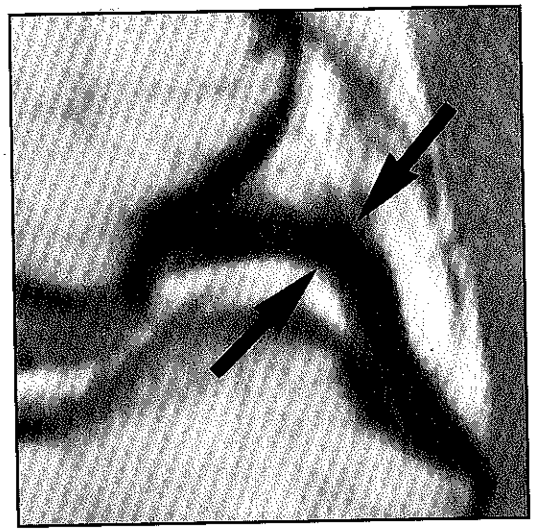


Fig 6: Normal PCL. Sagittal T1-weighted image. The normal PCL is a well defined band of homogeneous signal void (arrows).

Fig 7: Transverse meniscal ligament. Sagittal T1-weighted image. At its meniscal attachments, the ligament may simulate a tear of the anterior horn (arrow) (A). Adjacent images reveal the ligament (arrow) (B).

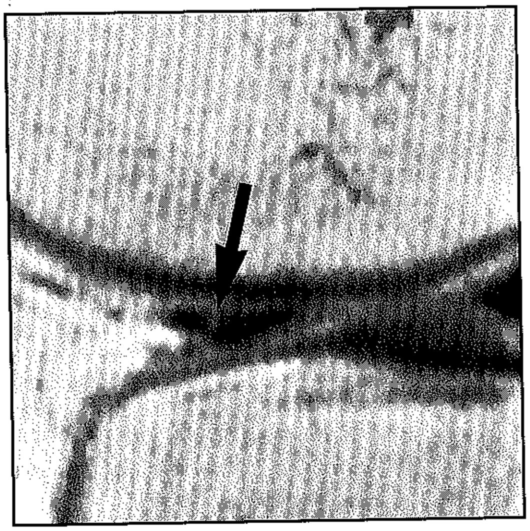


Fig 7A.

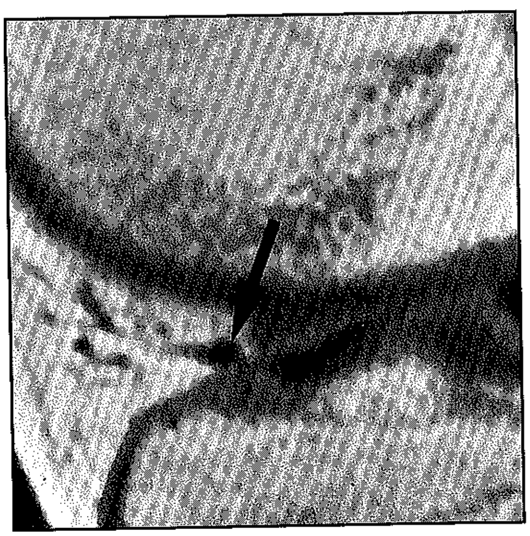


Fig 7B.

PCL tear is identified as abnormal intermediate signal within the ligament in T1-weighted images, and high signal intensity fluid in the ligament in T2-weighted images. Avulsion of the PCL may also occur. This is evident as a fracture of the tibia at the ligament attachment.

There are several normal variant structures in the knee which can be mistaken for pathology in MR images.[17,18] Recognizing these structures can avoid confusion and misdiagnoses. Three structures most commonly mistaken for pathology are the transverse meniscal ligament, the meniscofemoral ligaments, and the popliteal tendon sheath.

The transverse meniscal ligament is a normal structure which runs between the anterior horn of the medial and lateral meniscus. Near its meniscal attachments, the ligament may be separated from the meniscus by a thin band of intermediate signal intensity which may simulate a vertical or oblique tear of the anterior horn (Fig 7). This pitfall can be avoided by following the ligament across the fat anterior to the joint to its insertion on the opposite anterior horn.

The meniscofemoral ligaments are two normal variants found in the posterior knee. They originate at the posterior horn of the lateral meniscus, and run obliquely to insert on the medial femoral condyle (Fig 8). The anterior meniscofemoral ligament—the ligament of Humphrey—courses anterior to the PCL. It is present in 33% of routine knee MR images. The posterior ligament—the ligament of Wrisberg—courses posterior to the PCL. It is present in 33% of routine MR images. Both ligaments can be identified in 3% of the routine images. The primary potential for these structures is mistaking them for intraarticular loose bodies.

Another potential "pseudotear" is found associated with the posterior horn of the lateral meniscus. In this region, the popliteus tendon sheath is closely applied to the meniscus. A small amount of synovium or synovial fluid may appear as a band running obliquely or vertically through the posterior horn, and may simulate a tear.

THE SHOULDER

MRI allows excellent depiction of the anatomy of the shoulder.[19,20] This modality is proving useful in the evaluation of several common causes of shoulder pain.

In cases of impingement syndrome, MRI may

Fig 8: Meniscofemoral ligament (ligament of Wrisberg). Sagittal T1-weighted image. The ligament (arrow) should not be mistaken for a loose body.

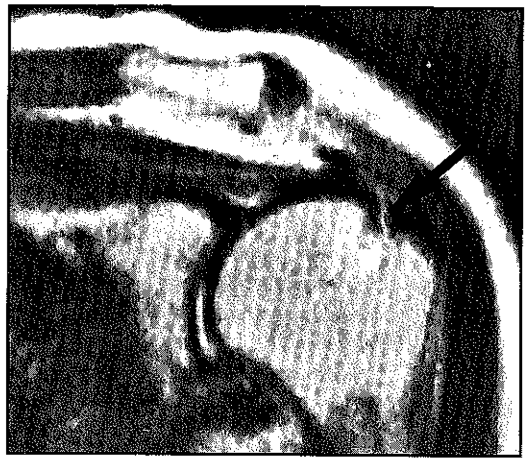


Fig 9: Supraspinatus tendon tear. Frontal oblique T2-weighted image. The focus of high signal intensity in the tendon represents a tear (arrow).

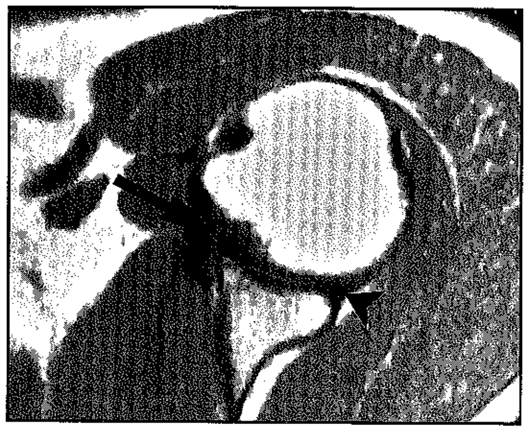


Fig 10: Normal glenoid labrum, anterior (arrow) and posterior (arrowhead). Axial T1-weighted image. The normal labrum is a homogeneous signal void.

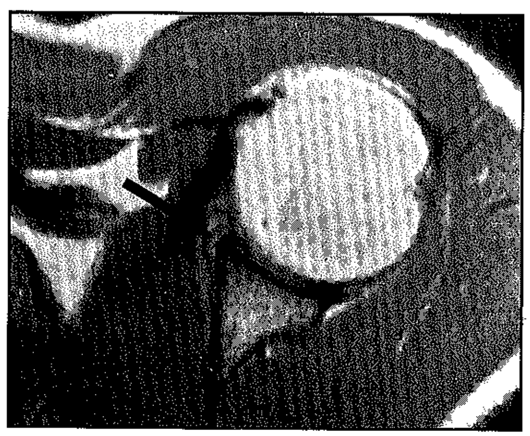


Fig 11: Anterior glenoid labrum tear. Axial T1-weighted image. The band of high signal intensity crossing the base of the anterior labrum indicates a tear (arrow).

be used to diagnose subacromial bursitis, supraspinatus tendinitis, and frank tendon tear.[21,22] Often, the offending structure inducing impingement can also be identified. This includes a low-lying anterior acromion, subacromial spur, degenerative changes of the acromioclavicular joint, or hypertrophy of the acromioclavicular joint capsule. The lesions of impingement syndrome are best depicted by imaging in the frontal oblique plane, along the long axis of the supraspinatus muscle.

Because the synovium of the subacromial bursa is both composed of and rests on fat, it normally appears as a thin band of high signal intensity in T1-weighted images. If the bursa is inflamed, this thin line of fat signal intensity will thicken, reflecting the hypertrophic synovitis associated with chronic impingement.

The tendons of the rotator cuff are normally low signal intensity in T1-weighted images. In cases of tendinitis, the signal of the tendon will increase in T1-weighted images, and remain either intermediate or become low signal intensity in T2-weighted images. If a frank tear is present, fluid will cause the tendon to appear intermediate signal intensity in T1-weighted images, and very high signal intensity in T2-weighted images (Fig 9).

MRI is also useful in the evaluation of glenohumeral instability and the glenoid labrum.[23-25] The normal glenoid labrum is a homogeneous signal void (Fig 10). The anterior labrum is larger than the posterior. Evaluation of the labrum should be similar to that of the meniscus in the knee, including size, internal signal characteristics, and contour. A labrum that is abnormally small may reflect degenerative wear or avulsion. Severe labral attenuation is also seen in patients with a history of multiple dislocations in which instance the labrum is "worn away." A frank labral tear appears as a band of intermediate to high signal intensity which extends to the labral surface (Fig 11).

Labral avulsions and capsular tears found with soft tissue Bankart lesions are also evident with MRI. If the labrum had been avulsed and displaced, it can often be identified as a free intraarticular loose body. Capsular tears are evident by the presence of high signal intensity fluid dissecting into the subscapularis musculotendinous unit.

SUMMARY

MRI is rapidly altering the presurgical evaluation for many forms of musculoskeletal pathology, and the indications for MRI will undoubtedly continue to grow. Because of the complexity of this modality and the ability to totally "miss" pathology by the inappropriate choice of imaging plane or pulse sequence, cooperation between the orthopedic surgeon and the radiologist is essential. A close working relationship is required for maximum diagnostic information to be obtained with each examination and for optimal patient care.

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