

MRI of the Knee Update

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The role of MR imaging in the evaluation of the pathologic knee has become firmly established. MR imaging provides a comprehensive evaluation of a wide spectrum of both intra- and extra-articular pathology involving the knee. As a result, it has replaced knee arthrography. More and more, orthopedic surgeons are relying on MR imaging of the knee to determine which patients should have therapeutic arthroscopy performed thereby reducing the number of unnecessary diagnostic arthroscopies.

TECHNIQUE

A dedicated phased array extremity knee coil is utilized to maximize signal-to-noise. The knee is positioned in approximately 15 degrees of external rotation in order to best visualize the anterior cruciate ligament. All three orthogonal planes are essential for adequate anatomic assessment. In general, intravenous gadolinium contrast agents are only utilized to document synovitis, tumor necrosis, or an abscess cavity. MR arthrography utilizing direct intra-articular injection of dilute gadolinium contrast agent is occasionally useful for distinguishing recurrent/residual meniscal tears from post-meniscectomy changes.

An example of a routine pulse sequence protocol includes: 1) fast spin-echo PD/T2-weighted sagittal spin-echo imaging (192 x 512); 2) T1-weighted coronal spin-echo imaging (192 x 512); 3) T2-weighted fast spin-echo coronal imaging with fat suppression; and 4) T2-weighted axial fast spin-echo imaging with fat suppression. The echo train length for the fast spin echo sequences is kept at or below eight (ETL < 8). "Meniscal windows" are routinely filmed which consist of magnification views of the menisci on the intermediate-weighted sagittal images windowed and leveled to optimally demonstrate meniscal pathology. Radial imaging of the menisci is not routinely performed as it has not consistently been demonstrated to improve the diagnostic yield with regard to meniscal disease.

Cartilage pathology such as chondromalacia patella frequently is poorly demonstrated on routine spin echo pulse sequences. Recent studies demonstrate that the following sequences are helpful for the evaluation of articular cartilage: fat-saturated T2-weighted FSE, T2*-weighted GRE utilized in conjunction with magnetization transfer contrast, DESS, and

3D fat-saturated spoiled GRE. At low field, a sandwich Dixon technique in conjunction with spin echo or gradient echo pulse sequences has demonstrated value.

Utilizing examples of these techniques, a search pattern approach to the wide spectrum of knee pathology will be presented. This search pattern approach should include assessment of the menisci, ligaments and tendons, osseous structures, articular surfaces, and adjacent soft tissues.

MENISCI

Meniscal tears are characterized by linear, complex, or diffuse increased signal intensity within the meniscus which communicates with an articular surface. Types of meniscal tears include: horizontal cleavage, radial, parrot beak, peripheral/vertical, flap, bucket-handle, meniscocapsular separation, complex, and macerated. The mechanism of injury of most meniscal tears is usually either valgus stress with external rotation or varus stress with internal rotation. The posterior horn is more commonly involved than the anterior horn, and the medial meniscus is more commonly involved than the lateral meniscus. Typical symptoms include swelling, locking, popping, and joint line tenderness. A positive McMurray's sign may be noted on physical examination. MR imaging accurately demonstrates the location, size, and type of meniscal tear thus facilitating appropriate treatment.

The incidence of meniscal cysts associated with meniscal tears is approximately 7 percent. These cysts are fluid collections arising from the peripheral margins of either horizontal cleavage tears or complex tears of the menisci. They are more commonly associated with lateral meniscal tears. They are frequently septated and may attain a size of up to 6 cm. These cysts are usually accompanied by lateralizing joint line tenderness. Treatment includes arthroscopic debridement/unroofing of the cyst associated with partial meniscectomy.

Developmental meniscal anomalies such as the discoid meniscus are also readily identified on MR imaging. The overall incidence of discoid meniscus is 1 percent. This anomaly affects the lateral meniscus much more commonly than the medial meniscus. Discoid menisci are associated with an increased incidence of meniscal tears as well as an increased incidence of meniscal cysts associated with these tears. Sagittal MR images suggest the diagnosis

when too many "bowties" are seen. The diagnosis is confirmed in the coronal plane where the involved meniscus is noted to extend too far into the joint space. There may be associated increased vertical thickness of the involved meniscus. Treatment includes partial meniscectomy/saucerization converting the disk-shaped meniscus into the more anatomic crescentic meniscus.

Many important pitfalls have been described with regard to interpreting MR imaging of the menisci. These include: normal high signal intensity in the menisci of children (especially adolescents); the meniscal ossicle; buckling of the meniscus (meniscal flounce); the insertion of the transverse geniculate ligament; the oblique intermeniscal ligament; the concave outer margin of the menisci; meniscofemoral ligaments; the popliteus tendon/sheath; popliteal artery phase ghost; and Gibbs artifact. MR imaging sensitivity and specificity for detection of a meniscal tear is decreased in the presence of meniscal chondrocalcinosis. Awareness of these potential pitfalls is essential to avoid overdiagnosis of meniscal tears. Overall, the MR evaluation of meniscal tears has a reported accuracy of 90-95%.

LIGAMENTS

The most frequently injured ligament in the knee is the anterior cruciate ligament. The most common mechanisms of injury are valgus stress or hyperextension. MR imaging best demonstrates the anterior cruciate ligament in the sagittal plane where its slope should be at least as steep as Blumenstaat's line. Axial and coronal planes are underutilized in the evaluation of the ACL, but can be very helpful. In most cases, the diagnosis of an ACL tear can be confirmed by direct MR imaging findings. In the acute setting, this includes increased signal intensity in the expected location of the ACL on T2-weighted images, discontinuity/nonvisualization of the ACL, and decreased steepness of the slope of the ACL compared with Blumenstaat's line. Occasionally, direct MR imaging findings of an ACL tear are equivocal. One must then rely on indirect MR imaging signs that frequently accompany ACL injury. These include: a Segond fracture; acute hemarthrosis; lateral femoral condylar notch sign; and bone contusions involving the posterolateral tibial plateau, mid lateral femoral condyle, or anterior femur and tibia

("kissing contusion"). Meniscal tears are associated with acute isolated ACL injuries in 40-60 percent of cases. It is the presence or absence of such associated intra-articular pathology that may determine whether a patient is treated conservatively or with ACL reconstruction. In large series, MR imaging has consistently demonstrated sensitivities, specificities, and accuracies well over 90 percent for the diagnosis of ACL tears. Mucoïd degeneration of the ACL may be mistaken for an ACL tear on MR imaging. Careful correlation with the clinical history and the "celery stalk" appearance on MRI may be useful in arriving at the correct diagnosis.

The posterior cruciate ligament is thicker and stronger than the anterior cruciate ligament. As a result, the PCL is injured less commonly. The most common mechanisms of injury include the "dashboard injury", and extreme hyperextension. The PCL is easily visualized on routine sagittal MR images as a curvilinear structure of homogeneous low signal intensity on all pulse sequences. In acute injuries, PCL tears may be difficult to recognize clinically with many misdiagnosed at the initial examination. The overall accuracy of MR imaging for the evaluation of PCL tears approaches 100 percent.

The medial collateral ligament of the knee is a broad band consisting of superficial and deep components separated by the tibial collateral ligament bursa. The MCL is the second-most commonly injured ligament in the knee. The most common mechanism of injury is valgus stress to the flexed knee. The injury can be isolated to the MCL, or may be associated with tears of the ACL, medial meniscus, and the medial/posterior joint capsule. On MR imaging, the medial collateral ligament is best evaluated in the coronal and axial planes. In the acute to subacute setting, edema in the soft tissues immediately superficial to the MCL is a very useful secondary sign of injury. Calcification of the proximal attachment of the MCL is thought to be a remote sequelae of trauma and is referred to as Pellegrini-Stieda disease. This calcific deposit is usually low signal intensity on T1-weighted and T2-weighted images, however, it may become ossified manifesting marrow signal intensity.

The lateral collateral ligament of the knee is part of the lateral collateral ligamentous complex. The LCL arises from the lateral femoral epicondyle and courses obliquely to join the biceps femoris tendon forming the conjoint tendon as it inserts on the fibular head. The most common mechanism of injury is varus stress with the leg in internal rotation. Components of the lateral collateral ligamentous complex are best demonstrated in the coronal plane with MR

imaging. Anteriorly, the iliotibial band is demonstrated as it inserts on Gerdy's tubercle. In the mid portion of the knee, the lateral capsule can be seen in close association with the lateral meniscus. More posteriorly, the lateral collateral ligament and biceps femoris tendon are seen forming the conjoint tendon insertion on the head of the fibula. A complete tear of the LCL is characterized by a wavy, irregular contour of the torn ligament with surrounding fluid/edema. There may be an associated avulsion fracture of the fibular head and occasional peroneal nerve palsy clinically. An associated injury of the ACL results in anterolateral instability while an associated injury of the remaining components of the arcuate complex results in posterolateral instability.

EXTENSOR MECHANISM

The extensor mechanism consists of the quadriceps muscle/tendon, patella, and patellar tendon. Injury involving the extensor mechanism is relatively uncommon. The mechanism of injury is usually indirect; especially strong quadriceps contraction opposed by forced flexion of the knee. Complete disruption of the extensor mechanism results in loss of extensor function and severe pain. The most common site of disruption of the extensor mechanism is the patella. Disruptions of the tendonous portion of the extensor mechanism tend to be suprapatellar above the age of 40 and infrapatellar below the age of 40.

Chronic patellar tendonitis includes both Osgood-Schlatter disease, and jumper's knee. The MR findings associated with these entities are similar, consisting of focal or fusiform thickening of the patellar tendon associated with increased intratendonous signal. In the case of Osgood-Schlatter disease, this is located near the tibial tuberosity while in the case of jumper's knee this is located near the inferior pole of the patella. Overlying subcutaneous edema is not uncommon, and there may be foci of low signal intensity due to osseous fragments.

OSSEOUS PATHOLOGY

A wide spectrum of osseous abnormalities have been described following trauma to the knee. Marrow edema almost always accompanies traumatic osseous lesions in the acute to subacute time frame. This includes not only the spectrum of bone contusion through cortical fracture, but also the parallel spectrum of stress reaction through stress fracture. A diffuse or localized pattern of low signal intensity on T1-weighted images without a defined fracture line is seen with bone contusions and stress reaction. If there is an associated cortical fracture or stress fracture, the MR images usually demonstrate a sharp, well-defined, linear segment of decreased signal intensity on all pulse sequences. In addition to associated marrow edema, there may be evidence of marrow hemorrhage acutely. Rarely, a stress fracture may be completely obscured on MR images by reactive edema requiring thin section, high resolution CT for confirmation. Several recent studies have demonstrated the cost effectiveness of MR imaging for the diagnosis of radiographically occult fractures. The recognition of bone contusions by MR imaging continues to represent a major contribution to sports medicine. These lesions are difficult to diagnose clinically or utilizing other imaging modalities and may

produce significant pain. If managed improperly, they can progress to actual cortical fracture.

Tension injuries involving ligaments tend to avulse bony attachment sites. While impaction type injuries cause a bone contusion or depressed fracture, distraction forces do not tend to be associated with marrow edema. As a result, avulsion fractures, such as Segond fractures, are difficult to identify by MR imaging unless the fracture fragment contains trabecular bone. The best way to identify these avulsion fractures is maintaining a high index of suspicion and looking at the specific locations where they occur. The only indication of fracture may be cortical discontinuity at the donor site. Correlation with plain radiography is usually very helpful.

Other categories of osseous/bone marrow pathology that commonly affect the knee include avascular necrosis/bone infarct, spontaneous osteonecrosis, subchondral insufficiency fractures, osteomyelitis, and primary or metastatic neoplasia. Examples of these entities will be presented.

ARTICULAR PATHOLOGY

Most articular pathology involves articular cartilage or synovium, with variable involvement of the subchondral bone. MR imaging of synovial hypertrophy/synovitis is significantly augmented by utilizing intravenous gadolinium contrast administration. Synovial disease processes such as rheumatoid arthritis, pigmented villonodular synovitis, synovial osteochondromatosis, and neoplastic involvement of the synovium are readily demonstrated with MR imaging.

Osteochondritis dissecans typically affects young males and usually involves the nonweight-bearing surface of the medial femoral condyle. A history of knee trauma is present in approximately 50 percent of cases. MR imaging is useful for both the diagnosis and staging of osteochondritis dissecans. The determination of OCD fragment stability based on MR imaging findings is helpful in determining treatment. MR imaging findings that have a high correlation with fragment instability include imbedded high signal intensity subchondral fluid surrounding the osteochondral fragment, focal cystic changes deep to the lesion, and the presence of a free osteochondral loose body.

One of the most common forms of articular pathology is osteoarthritis or degenerative joint disease. Typically, this entity is evaluated with conventional radiographs. More recently, MR imaging has allowed

early detection of subtle cartilaginous and joint space changes in this type of arthropathy. MR imaging findings reflect the spectrum of pathologic findings in osteoarthritis including: marginal osteophyte formation; thinning of articular cartilage; joint space narrowing; subchondral sclerosis; subchondral cyst formation; and osteochondral loose body formation. Both osteophytes and ossified loose bodies demonstrate yellow marrow signal intensity on all pulse sequences. Subchondral sclerosis manifests decreased signal intensity on all pulse sequences in a wedge-shaped or flame-shaped morphology. Subchondral cyst formation manifests fluid signal intensity on all pulse sequences.

SOFT TISSUE PATHOLOGY

Soft tissue masses are relatively common musculoskeletal problems in the knee. The diagnosis of these lesions is complicated by an extensive differential diagnosis including a wide variety of categories of disease. The initial imaging study of a soft tissue mass should be conventional radiography. When additional cross-sectional imaging is required, MRI is usually the imaging modality of choice. The major exception is evaluation for calcification or ossification associated with a soft tissue mass which is still better evaluated with either CT alone or in combination with MRI. Overall, MRI demonstrates the extent of disease better than CT and yields a specific diagnosis in 30-40 percent of cases. If MRI fails to be diagnostic, the mass should be regarded as possibly malignant. Remember, that biopsy remains the only definitive diagnostic procedure in such cases. In the 30-40 percent of cases where MRI is sufficiently diagnostic, biopsy can be avoided.

Included within the differential diagnosis of soft tissue masses in the knee are a number of entities that present as cystic appearing masses on MR imaging. Table I lists the differential diagnosis of such cystic appearing masses in the knee. The axial plane is frequently the most helpful for distinguishing the etiology of the cystic

appearing masses. Caution must be exercised when diagnosing cystic soft tissue masses with MR imaging. Some malignant lesions may appear well circumscribed, with homogeneous fluid signal intensity on MR imaging. Examples include myxoid neoplasms such as myxoid liposarcoma and other highly malignant lesions such as synovial cell sarcoma. Ultrasound remains the only imaging modality that truly distinguishes cyst versus solid mass.

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Table I. Cystic Appearing Masses in the Knee

Effusion	Bursitis
Meniscal Cyst	• Pes Anserinus
Ganglion Cyst	• Prepatellar
Cruciate Cyst	• Infrapatellar
Synovial Cell Sarcoma	• Gastrocnemius
	• Tibial Collateral Ligament
	• Popliteal/Baker's Cyst
	• Semimembranosis-Tibial Collateral Ligament

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