

# MR imaging of the knee: current concepts

Kim Jansson, MD, PhD, Seppo Koskinen, MD, PhD

Helsinki University Central Hospital, Helsinki, Finland

Magnetic resonance imaging (MRI) has revolutionized the evaluation of musculoskeletal soft tissue disorders. This is most evident in the evaluation of internal derangements of the knee. MRI is an accurate and cost-effective means of evaluating a wide spectrum of knee injuries, ranging from cruciate-collateral ligament injuries to cartilage deficiencies.

For clinicians and radiologists, evaluation of an injured knee using MRI requires knowledge of the proper imaging techniques, normal anatomy and most common variants, and the clinical significance of detected abnormalities.

Advances in magnetic field strength, gradient strength, and coil design have facilitated the development of new pulse sequences, which have partly transformed knee MRI from routine morphologic imaging to molecular imaging. This article will review current MRI concepts of meniscal and cruciate ligament tears, as well as new developments in MRI of the knee such as 3-T imaging and techniques for meniscus and cartilage imaging.

## 3-tesla imaging

The introduction of high-field-strength MRI offers substantial advances in musculoskeletal applications. Higher magnetic field provides more signal to noise than lower field strength magnets. This higher signal to noise can then be traded for either higher resolution images or faster imaging times. There is limited amount of published evidence comparing musculoskeletal imaging at 1.5 T versus 3.0 T. Clinical experience, however, does exist. It can be anticipated that the faster image acquisition at 3.0 T should translate into an increased imaging accuracy, or an improved diagnosis (1). High field imaging allows three-dimensional imaging of the knee, in which single scan sequence can be reformatted into any plane. Also, this technique allows "virtual arthroscopy", a feature found to be useful in presurgical planning by surgeons.

However, 3T imaging is not without disadvantages. There is increased susceptibility artifact (imaging around metal instrumentation is difficult), there is increased chemical shift artifact leading to increased misregistration at fat-water interfaces (requiring adjustments in bandwidth). In addition, tissue heating

in patients due to higher energy deposition is a potential hazard that requires attention to the scanning parameters. Also, signal behavior is different due to different T1 relaxations times in higher field strengths.

## Cruciate ligaments

A cruciate ligament injury is usually diagnosed on the basis of the patient's history and physical findings or MRIs. The skilled clinician can diagnose as many as 90% of ACL tears based on history and physical examination findings (2). MRI is the study of choice to evaluate the cruciate ligaments of the knee. MRI may alter the treatment by allowing confident diagnosis or exclusion of an ACL tear in patients with equivocal physical examination findings; however, the greatest contribution of MRI in ACL-injured patients is in the evaluation of accompanying injuries such as posterolateral-corner PLC (lateral collateral ligament complex), PCL, and meniscal tears. Studies report variable 78-100% sensitivity and 68-100% specificity of MRI for the diagnosis of ACL tears. Difficulties in diagnosis of proximal, partial, or chronic tears account for many of

the errors in evaluation of the ACL. Sensitivity is also significantly decreased if other major ligamentous injuries are present in the knee (3).

The PCL is less commonly injured than the ACL, but demonstrates the same range of appearances on MRI. Other knee injuries are highly associated with PCL tears. Regardless of the imaging modality used, it can be difficult to differentiate partial from full-thickness tears of the PCL.

## Meniscus

MRI is the preferred imaging modality for evaluating meniscus, with high accuracy reported in most studies. Each sequence has investigators who support its use; however, a pooled summary of published articles between 1991 and 2000 reports a sensitivity and specificity with MR imaging of 93% and 88% for medial, and 79% and 95% for lateral meniscal tears. The differences in sensitivity and specificity could be related to the sequences used, observer variation, or sample size. The sensitivity for detecting meniscal tears usually is higher in the medial meniscus regardless of the technique used (4). In patients who have partial meniscal resection or repair, diagnosing a recurrent tear is more complicated, and the use of T2 fat-saturated coronal and sagittal sequences is recommended. If there is knowledge of resection of more than 25% of the meniscus or a meniscal repair, most advocate the use of direct MR arthrography (5).

Ultrashort TE imaging is a technique in which the normal meniscus demonstrates increased signal and tears have decreased signal, and is performed best without fat suppression. In contrast to fat-suppressed T1-imaging with intravenous contrast agent gadolinium, which cannot differentiate between the vascular and avascular zones of the meniscus, contrast administration on ultrashort TE images can make this differentiation (6).

Higher diagnostic confidence is reported with 1.5T imaging, as opposed to 0.2T imaging, for the diagnosis of meniscal tears, probably because of the inherent increased signal-to-noise ratio at 1.5T. Recent developments in the area of 3T and faster imaging techniques are not yet evaluated fully, but offer promise for accurate meniscal evaluation with even shorter scan times. Three-tesla MR imaging is highly accurate in detection of meniscal tears. This detection aids referring physicians, because if a meniscal tear is not seen on 3-tesla MR imaging, it is highly unlikely

to be present. However, it must be kept in mind that not all meniscal tears are symptomatic (7).

## Cartilage

Delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) is a relatively new technique aiming to assess the hyaline cartilage tissue, giving details not only for the morphologic features but also for its structural features. This technique uses intravenous contrast agent (gadolinium) contrast to indirectly measure the glycosaminoglycan (GAG) concentration of articular cartilage. Colour can be applied to the data to make a qualitative colour map of regions of contrast uptake. However, the correlation between MRI parameters and clinical outcome seems to be limited (8). Future development includes the ability of cartilage MRI to noninvasively detect early changes in the matrix before morphologic alteration, thus aiding in the decision regarding the optimal timing of surgical procedures designed to delay the progression of osteoarthritis. The T2 assessment of articular cartilage, on the other hand, and 3T MRI are gaining clinical acceptance for the evaluation of osteoarthritis and its related conditions. The T2 relaxation time (T2 value) is a measurable MRI parameter. T2 relaxation mapping has been introduced to assess early biochemical changes in cartilage degeneration prior to morphological changes (9).

## MRI limitations

The usefulness of MRI is limited in patients with claustrophobia, who are obese, or who have a pacemaker. Its usefulness is also limited by the presence of artifacts created by nearby orthopedic hardware. Depending upon the implant utilized, a varying amount of artifact is observable on MRI at the location of the fixation material. However, use of non-ferromagnetic metals such as titanium has reduced the amount of artifact in the postoperative knee (10). Following the use of bioabsorbable screws, a less severe imaging artifact is apparent. The additional benefit of bioabsorbable screws is that any associated artifacts tend to diminish over time.

The use of open MRI units, as well as dedicated extremity units, has decreased the number of patients for whom MRI cannot be used because of claustrophobia or obesity. For patients with contraindications to MRI, computed tomography (CT) arthrography

should be considered the alternative imaging modality.

#### **References**

1. Kuhl CK, Traber F, Gieseke J, Drahanowsky W, Morakkabati-Spitz N, Willinek W, et al: Whole-body high-field-strength (3.0-T) MR imaging in clinical practice. Part II. Technical considerations and clinical applications. *Radiology*. 2008;247(1):16-35.
2. Johnson DL, Warner JJ: Diagnosis for anterior cruciate ligament surgery. *Clin.Sports Med*. 1993;12(4):671-684.
3. Rubin DA, Kettering JM, Towers JD, Britton CA: MR imaging of knees having isolated and combined ligament injuries. *AJR Am.J.Roentgenol*. 1998;170(5):1207-1213.
4. Oei EH, Nikken JJ, Verstijnen AC, Ginai AZ, Myriam Hunink MG: MR imaging of the menisci and cruciate ligaments: a systematic review. *Radiology* 2003;226(3):837-848.
5. Fox MG: MR imaging of the meniscus: review, current trends, and clinical implications. *Radiol.Clin.North Am*. 2007;45(6):1033-1053.
6. Gatehouse PD, Thomas RW, Robson MD, Hamilton G, Herlihy AH, Bydder GM: Magnetic resonance imaging of the knee with ultrashort TE pulse sequences. *Magn.Reson.Imaging*. 2004;22(8):1061-1067.
7. Englund M, Guermazi A, Gale D et al: Incidental Meniscal Findings on Knee MRI in Middle-Aged and Elderly Persons. *N Engl J Med*. 2008;359:1108-1115.
8. Vasiliadis HS, Danielson B, Ljungberg M, McKeon B, Lindahl A, Peterson L: Autologous chondrocyte implantation in cartilage lesions of the knee: long-term evaluation with magnetic resonance imaging and delayed gadolinium-enhanced magnetic resonance imaging technique. *Am.J.Sports Med*. 2010;38(5):943-949.
9. Domayer SE, Kutscha-Lissberg F, Welsch G, et al: T2 mapping in the knee after microfracture at 3.0T: correlation of global T2 values and clinical outcome – preliminary results. *Osteoarthritis Cartilage*. 2008;16:903–908.
10. Suh JS, Jeong EK, Shin KH, Cho JH, Na JB, Kim DH, et al: Minimizing artifacts caused by metallic implants at MR imaging: experimental and clinical studies. *AJR Am.J.Roentgenol*. 1998;171(5):1207-1213.