

of numerous research studies over the past several years. There are several reasons: the essential role articular cartilage plays in the function of the diarthrodial joints of the body, the high prevalence of degeneration and traumatic injury of articular cartilage, and the recent development of new surgical procedures that hold the promise of forming repair tissue that is hyaline or hyaline like cartilage. This imaging method has great promise and may emerge as an effective technique for detecting even the early stages of chondral abnormalities. MR imaging is the most important imaging modality for the evaluation of traumatic or degenerative cartilaginous lesions in the knee. Apart from MR imaging techniques that depict cartilage morphology, there is growing interest in developing MR imaging techniques that are sensitive to early structural damage in articular cartilage. Two techniques that have demonstrated promise are quantitative T2 mapping and T1 mapping with delayed gadolinium-enhanced MR imaging of cartilage after administration of gadopentetate dimeglumine<sup>17</sup>.

Imaging articular cartilage is a challenge. It is thin, with a maximum thickness of about 4 mm, and usually has curved surfaces. To obtain high-quality MR images, one must maintain a balance between high spatial resolution and adequate SNR. Any increase in the SNR that can be obtained affords the potential to increase the spatial resolution and thus to improve MR image sensitivity for small abnormalities and early disease in articular cartilage. For example, a new MRI system that provides a twofold improvement in SNR should be able to provide a twofold increase in spatial resolution at the same SNR as the old system.

Because SNR is linearly proportional to magnetic field strength, imaging at higher magnetic field strengths should allow greater spatial resolution with equal imaging time and SNR. If all other factors were to remain equal, a change from a 1.5-T system to a 3-T system, for instance, should provide a twofold increase in SNR at the same spatial resolution and imaging time, a twofold increase in spatial resolution at the same SNR and imaging time, or a fourfold reduction in imaging time at the same SNR and spatial resolution. However, at higher field strengths, the T1 relaxation times increase, particularly for cartilage. Also, the increase in frequency difference between marrow fat and cartilage water at 3 T versus lower field strength reduces the benefits obtained from an increase in magnet field strength for non-fat-suppressed methods. Longer T1 relaxation times require longer-pulse TRs, resulting in an increase in image acquisition time or a change in the flip angle of the excitation pulse to maintain the same image contrast at higher field strength. In addition, for non-fat-suppressed images, the greater separation of fat and water frequencies will lead to greater chemical shift artifacts at the cartilage-bone interface because of marrow fat. Although increasing the bandwidth of the image acquisition may reduce this artifact, the SNR of the acquisition decreases. Despite these challenges, high-field imaging shows great promise as an overall improvement in articular cartilage assessment by MRI.

New pulse sequences and image acquisition methods under development for articular cartilage have focused on image contrast and spatial resolution that would improve both quantitative cartilage analyses and the clinical diagnosis of articular cartilage abnormalities. A major emphasis of articular cartilage research has been the measurement of articular cartilage thickness and volume as biomarkers for disease progression or treatment response in osteoarthritis. To perform these analyses, it is desirable to use computer algorithms to identify, or "segment," articular cartilage tissue in an automated manner. This goal requires high image contrast between cartilage and the surrounding tissues, including bone, bone marrow, joint fluid, menisci, joint capsule, ligaments, and intraarticular fat. To

date, no one acquisition sequence has proven ideal, although the majority of publications on volume and thickness measurements have used the 3D T1-weighted SPGR sequence. Although this sequence shows good cartilage-water and cartilage-fat image contrast, the cartilage-meniscus and cartilage-capsule image contrast has been relatively poor. Automated and semi-automated image-processing approaches that combine two image acquisitions—for example, subtraction of image acquisitions with and without binomial pulse saturation transfer—have shown the ability to isolate articular cartilage automatically for volume and thickness measurements. However, double-acquisition techniques can be time-consuming and may require image registration if the patient moves between acquisitions.

## TO CONCLUDE

The preceding is only a partial list. MRI continues to be a fertile area for technological advances:

- Signal Processing and Image Reconstruction
- RF technology
- Magnet technology
- Contrast mechanisms

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