Summary
The ability of noninvasive magnetic resonance imaging (MRI) to obtain reproducible, accurate images of cartilage has enabled early detection of cartilage lesions and provides clinically relevant information when planning cartilage repair. With appropriate pulse sequencing, MRI depicts not only the integrity of the surface cartilage, which would be seen at arthroscopy, but also that of the subchondral bone, which would not be visualized at arthroscopic inspection. This information is vital when planning for complex, sometimes multistage, techniques that require careful size delineation of the cartilage lesion and evaluation of the surrounding subchondral bone. In addition to aiding in preoperative planning, these techniques offer an important objective evaluation of cartilage repair to be correlated with the more subjective clinical outcome instruments and provide insight into the biology of the repair process. Finally, newer matrix assessment techniques will disclose information about the ultrastructure of these individual cartilage repair procedures.

Key Words: Cartilage; cartilage repair; MRI; T₂ mapping.

CARTILAGE IMAGING TECHNIQUES
Arguably one of the greatest contributions that magnetic resonance imaging (MRI) has made in the past decade has been the ability to assess articular cartilage noninvasively and accurately. Despite the increasing availability of sophisticated imaging techniques, conventional radiographs remain the mainstay for assessment of the joint space. It is important to remember that conventional radiographs do not directly depict the articular cartilage but instead provide an indirect measure of cartilage loss. For the knee, a typical initial imaging assessment includes an anteroposterior standing view as well as a posteroanterior semiflexed (30–60°) view, with the latter best suited to assess the posterior margin of the joint space, where cartilage is often initially degraded. Additional lateral and Merchant views are helpful for assessing patellofemoral alignment and joint space. Full hip-to-ankle anteroposterior views are essential when planning for cartilage repair, in order to assess the true mechanical axis of the limb.

Although radiographs remain the standard for this initial assessment, MRI is rapidly supplanting standardized techniques because of its ability to visualize articular cartilage directly and accurately, allowing for accurate, reproducible measurements of cartilage thickness and assessment of morphologic changes over time. MRI is superior to both conventional radiographs and computed tomography because of its direct multiplanar capabilities and superior soft tissue contrast. As such, MRI allows for the detection of isolated full-thickness cartilage
defects; these defects are typically imperceptible on conventional radiographs because of the preservation of joint space and integrity of the subchondral bone.

Many magnetic resonance (MR) pulse sequences are available for assessment of cartilage. It is important to remember that traditional spin echo techniques, including $T_1$-weighted sequences, are ineffective in assessing cartilage because of the often poor in-plane resolution and tissue contrast (1,2). In particular, on $T_1$-weighted techniques for which the fatty signal of the cancellous bone is bright, cartilage is poorly differentiated from the surrounding soft tissue as both cartilage and fluid maintain intermediate-to-lower signal intensity. The first validated cartilage pulse sequences (using arthroscopy as a standard) were the three-dimensional (3D) fat-suppressed gradient echo techniques, allowing for very high contrast between the low signal intensity of the suppressed cancellous bone and the high signal intensity of the surrounding cartilage (Fig. 1). Several studies have utilized these techniques with sensitivity ranging between 81 and 93% and specificity ranging between 94 and 97% (3,4).

Volumetric gradient-recalled techniques, particularly when obtained with square voxels, are more amenable to automatic segmentation and volume quantification methods, allowing for 3D assessment of cartilage volume and thickness (5). These techniques have been validated utilizing both clinical and nonclinical models with good degrees of reproducibility (6). These gradient echo techniques, however, are lengthy and subject to susceptibility artifact generated by the metallic debris left by arthroscopy or the presence of instrumentation that may accompany cartilage repair techniques. They are also less sensitive to surface fibrillation.

In an attempt to validate a pulse sequence that was not subject to these limitations, Potter et al. evaluated 88 patients with a fast spin echo (FSE) technique, using arthroscopy as the

Fig. 1. Sagittal fat-suppressed three-dimensional gradient echo magnetic resonance imaging of the knee in an 11-yr-old boy demonstrates high contrast between the low signal intensity bone and the bright articular and physeal cartilage.