Osteoarthritis (OA) remains a leading cause of disability, affecting more than half the population by the age of 65. Numerous MRI methods including T2 mapping, delayed gadolinium enhanced MRI of cartilage (dGEMRIC), T1rho, sodium, quantitative 3D volume and thickness measurements, magnetization transfer and chemical exchange saturation transfer (CEST) continue to be explored as non-invasive measures of cartilage change. All of these methods have their strengths and weaknesses, relating to practicality/robustness and sensitivity to various stages of cartilage change. However despite a need for imaging biomarkers of early change in OA in order to better understand the disease process as well as to develop new therapies, no single method has emerged as a complete solution. A method that has received relatively little study is diffusion weighted imaging.

Diffusion MRI: The effects of diffusion in magnetic resonance have been studied since well before MRI itself. After excitation, random motion of water in the presence of any gradient causes a loss of signal when the effect of the gradient is refocused. The most common diffusion-weighted imaging (DWI) sequence uses a pair of identical gradients on either side of a 180° refocusing RF pulse. This image information is read out at the spin echo, often using a single-shot echo-planar readout to avoid motion-induced phase changes from corrupting the image. The sequence is sensitized to motion in the direction in which the diffusion gradients are applied. When the diffusion is isotropic, the signal attenuation is relatively independent of this direction, and typically the diffusion is characterized by the apparent diffusion coefficient (ADC). However, in cases of restricted diffusion, by repeating the scan with different diffusion directions, the diffusive motion can be more completely characterized using a technique called diffusion tensor imaging (DTI).

Diffusion in Cartilage: Diffusion is the primary transport mechanism for nutrients into cartilage, and is affected by the collagen matrix structure as well as interactions with proteoglycan. Most previous studies have shown that MRI-measured water diffusion is relatively isotropic, perhaps because any restricted diffusion due to collagen structure affects bound water for which the T2 relaxation time is too short to observe signal in diffusion-weighted imaging (DWI). ADC maps show a spatial variation from about 1.0 to 1.5 \( \mu m^2/\text{ms} \) across normal cartilage and in damaged cartilage. ADC increases in damaged cartilage. ADC increases of 10-27% have been shown in proteoglycan-depleted cartilage, with linear correlation to PG loss. Therefore DWI may offer another measure with which to probe cartilage change.

Challenges of Diffusion MRI of Cartilage: The primary difficulty of measuring diffusion in cartilage in vivo is the low signal that results from the relatively long echo time in DWI sequences and the short to medium T2 relaxation time in cartilage. Stronger gradients and higher field strengths are helping to address this challenge. An alternative approach is to use 3D “steady-state” imaging techniques, which avoid complications of EPI while also enabling observation of diffusion in short-T2 tissues. These methods have been used to make “relative” cartilage diffusion maps, but care must be taken to remove the confounding effects of relaxation on diffusion measurements.

References