CAD of Musculoskeletal MRI: Feature Detection using $T_2$ & $T_{1\rho}$ Relaxometry
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The increasing elderly population and sports-related injuries have made knee osteoarthritis (OA) a leading pathology causing patient disability. The integrity of cartilage tissue is a significant factor in the initiation and progression of knee OA. Cartilage integrity is provided by the collagen 3D mesh-like framework into which proteoglycans (PGs) are entrapped, by the interaction of glycosaminoglycans (GAGs; negatively charged polysaccharide) and $^{23}$Na ions in the vicinity, and by the high concentration of $^{23}$Na that produces osmotic pressure. These factors promote the absorption of large amounts of water into the extracellular matrix, which induces a high swelling pressure, thus providing the favorable load-bearing properties of cartilage [1].

MRI is widely used for the clinical diagnosis of knee OA, and morphologic studies measuring the cartilage thickness and volume have shown that knee OA is usually accompanied by cartilage thinning and loss. However, it has also been suggested that prior to these morphologic events, the cartilage biochemical composition experiences changes that can be captured by MRI relaxation time measurements. MRI $T_2$, and more recently $T_{1\rho}$ and $T_{1Gd}$ (delayed gadolinium enhanced MRI contrast, dGEMRIC) relaxation times have emerged as potential noninvasive cartilage degradation biomarkers in studies of knee OA.

MRI $T_2$ relaxation time is a parameter sensitive to biochemical changes, particularly changes in water, collagen content and tissue anisotropy [2]. $T_{1\rho}$ probes the slow motion interactions between motion-restricted water molecules and their local macromolecular environment, and therefore provides unique biochemical information in the low-frequency regime, typically from a few hundred hertz (Hz) to a few kilohertz (kHz) [3]. Delayed gadolinium-enhanced MRI can be used to study cartilage GAG content and distribution based on the distribution of the contrast agent Gd-DTPA$^{2-}$, which is calculated based on the $T_1$ relaxation time of the tissue [4].

In this course, we will focused on the quantification of contrast-free agent MRI relaxation times, specifically $T_2$ and $T_{1\rho}$. The quantification of these two MRI relaxation times follows a similar approach. Typically, $T_2$-weighted ($T_{1\rho}$-weighted) images with varying echo times (times of spin-lock) are acquired. Assuming exponential decay, $T_2$ ($T_{1\rho}$) maps can be generated on a pixel-by-pixel basis by fitting the time signals. Cartilage regions of interest can then be defined and relaxometry quantification performed.

Cartilage studies of knee OA involving $T_2$ and $T_{1\rho}$ relaxation times have been conducted based on:
1. Full-thickness mean values.
2. Z-score maps.
3. Laminar analysis.
4. Texture analysis.
5. Texture-based laminar analysis.

In this course, we will discuss in detail the different pre-processing and MRI $T_2$ and $T_{1p}$ relaxation time quantification approaches. The clinical utility of computer-aided diagnosis of knee OA based on relaxation time features will also be discussed, as well as future directions in the field of knee OA and other MRI MSK relaxometry applications such as intervertebral disk degeneration.

References