

Specialty area: Advanced Diffusion Acquisition: Targeted Methods

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Highlights:

- Both articular cartilage (AC) and intervertebral discs (IVD) are composed by a glycosaminoglycan (GAG) gel embedded on a structured collagen matrix.
- The interaction between GAG and collagen result in the unique mechanical properties of IVD and AC.
- Early pathological changes in osteoarthritis (AC) and in degenerative disc disease (IVD) involve loss of GAGs and disruption of the collagen architecture.
- With diffusion imaging we can explore changes in GAG and the collagen in AC and IVD.

Title: Intervertebral Discs and Cartilage

Target audience: MSK radiologist and MR physicists with interest in MSK applications of diffusion imaging

OBJECTIVE: After attending this lecture you will:

- Learn the basic biology of AC and IVD
- Understand the value of DTI of AC and IVD to detect early pathological changes
- Identify the advantages and disadvantages of the diffusion sequences used for AC and IVD.
- Have an up-to-date review of diffusion imaging in the AC and IVD

PURPOSE: To provide insight in the acquisition and clinical use of DTI of AC and IVD.

METHODS: The IVD is a relative thick structure (~1 cm) with long relaxation times ( $T_2 \sim 60$  ms), while the AC has much lower thickness (~3 mm) and relaxation times ( $T_2 \sim 30$  ms). The  $T_2$  values of IVD and its relative thickness allows using single shot sequences such as echo planar imaging (EPI) or single shot turbo spin echo sequences (sSTSE). Due to the elongated FOV required for a sagittal image of the spine, EPI and sSTSE sequences can achieve resolutions of the order of 1 mm with echo times of around 80 ms and are therefore broadly used to image IVD.

For diffusion imaging of AC single shot sequences do not deliver an appropriate image quality due to the short  $T_2$  times and the submillimeter in plane resolution (~0.6 mm) needed. Spin echo (SE) sequences have high signal-to-noise (SNR) efficiency and are insensitive to magnetic field inhomogeneity but have long acquisition times. A variant of the SE called line scan diffusion imaging sequences (LSDI) reduces the acquisition time and has been successfully used for diffusion in AC and IVD. Diffusion-weighted single shot free precession (SSFP) sequence provides fast acquisition with high SNR. However, the quantification of diffusion with SSFP images is very complex.

RESULTS: AC: Ex vivo studies of diffusion of articular cartilage demonstrated increase of the average diffusion after selective removal of the GAG [1]. More recently, ex vivo DTI studies showed that the orientation of the first eigenvector correlate with the arrangement of the collagen fibers as measured with polarized light microscopy and scanning electron microscopy [2,3]. Depletion of GAG results in increase of the mean diffusivity (MD) but in no change in fractional anisotropy (FA) [4, 5]. In AC samples with early signs of osteoarthritis, DTI could identify the degraded samples with high accuracy (95%) [6]. The first in vivo DTI study including healthy and OA patients demonstrated an excellent accuracy (92%) in differentiation of healthy and OA subjects [7].

IVD: Ex vivo studies showed different diffusion properties in the central part of the IVD (nucleus pulposus) and the surrounding annulus fibrosus [8]. In a high resolution ex vivo study, DTI maps showed the annular structure of the annulus fibrosus [9]. A decrease in MD with age and disc degeneration is observed as a consequence of a reduction of the water content in the inner part of the disc (nucleus pulposus) associated with a significant GAG loss [8]. Several in vivo studies have consistently demonstrated the reduction of MD with moderate disc degeneration and increased MD with severe disk degeneration [10,11]. However, the clinical use of MD may be limited by the overlap in the MD values of healthy and degenerated IVD [12]. Recently a study investigated the changes of the IVD with age using DTI and observed a significant decay in MD with age of 11% and an increase in FA of 20% [13].

CONCLUSION: Diffusion imaging is a promising technique to explore the integrity of the tissue microstructure in AC and IVD with potential for the early diagnosis of degenerative diseases.

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