

Optimisation of fast-field cycling for early detection of osteoarthritic cartilage

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In contrast to conventional nuclear magnetic resonance (NMR) experiments where a static magnetic field is applied to a sample, the applied field in field-cycled (FFC) NMR is altered during the experiment. Measurements of spin-lattice relaxation rate (R_1) as a function of applied field reveal interactions between water/protein protons and protein nitrogen nuclei (quadrupolar peaks; QP), the latter being proportional to protein concentration. In this study, the effect of different pulse sequences on the QP amplitude of cartilage samples taken from patients with and without osteoarthritis (OA) was examined. This may have clinical significance in detection of early stage osteoarthritis in vivo.

After favourable ethical review was granted, patients were recruited prior to joint replacement surgery for either hip fracture (n=12) or OA (n=15). The hip fracture patients did not have pre-existing OA clinically or radiographically. As routine protocol for the surgical procedure, the femoral head was removed and collected. Cartilage samples were subsequently harvested from the femoral heads.

Two experiments were designed using inversion recovery to assess QP amplitude. The first used saturation readout with 500 points over 50 μ s whereas the second used CPMG readout with 4096 point over 81 ms. R_1 was estimated by mono-exponential curve fitting.

Significant differences in the QP amplitude were found between normal patients and those with OA from the saturation experiment (2.17 vs. 3.49; $p < 10^{-10}$). However, CPMG experiments did not show significant difference between groups and the QP amplitude was significantly lower (1.61 vs. 1.41; $p < 0.14$).

The differences observed between saturation and CPMG are attributed to the short-lived NMR signal from cartilage proteins caused by the solid structure of their matrix. Fast measurements obtained directly after saturation pulses likely contain protein signal, which varies with cartilage condition, whereas the CPMG sequence fails to measure the fast-decaying protein signal. With CPMG, it is likely only water signal is recorded, which is shown to be uncorrelated to the cartilage condition in our experiment.

Clinical experiments must therefore include a fast detection technique in order to take advantage of the large difference observed between OA and normal cartilage by FFC MRI.