Relaxation Times Obtained by Dipolar Echo Techniques – a New Diagnostic Tool for Osteoarthritis

H. Shinar[1], K. Keinan-Adamsky[1], and G. Navon[1]
[1]School of Chemistry, Tel Aviv University, Tel Aviv, Israel

Introduction: The laminar appearance of cartilage in MRI is related to the residual dipolar interaction originating from anisotropic re-orientation of the water molecules in the vicinity of the oriented collagen fibers. The transverse relaxation rate of the water protons, R_2, has three major contributions: a) intramolecular dipolar interaction modulated by isotropic reorientation; b) proton exchange with chemically shifted OH and NH groups; c) residual dipolar interaction (RDI) due to anisotropic re-orientation of the water molecules interacting with the oriented collagen fibers. This interaction is the major contribution to the water T_2 in cartilage and is responsible for the dependence of T_2 on the orientation of the plug relative to the field. Since the proteoglycans (PG) do not have a significant contribution to the RDI, T_2 is insensitive to their amount.

In this work we present results obtained by dipolar echo sequence: the relaxation times obtained are significantly prolonged, are orientation independent and enable to clearly distinguish between control and osterarthritic cartilage.

Methods: Articular cartilage-bone plugs were excised from bovine femoral condyles. Control human femoral heads were obtained from the bone transplantation center and human osteoarthritic femoral heads were obtained from hip replacement surgery. Excised, 8 mm cartilage-bone plugs were equilibrated in saline, blotted dry and immersed in Fluorinert for NMR measurements. For PG depletion plugs were incubated with 1mg/ml trypsin in PBS. T_2 was measured by multi slice multi echo technique with TE ranging from 2-200 ms. Relaxation time by dipolar echo, T_{DE}, was measured by the following sequence: $\mathbf{90^0 - [\tau_{cp} - 90^0 - \tau_{cp}]_n}$ **– Imaging** (1,2) where τ_{cp} was 50 μs and n was in the range of 20 – 2400. The signal intensity as a function of TE at each spatial location on the cartilage bone plug was fitted to either a bi- or mono-exponential decay function (3).

Results: T_2 and T_{DE} for a bovine cartilage bone plug, as a function of the location on the plug are given in Fig.1. The results are given for the plug positioned with plug's normal parallel to the field and at 55^0 to the field. T_2 is very short at the parallel orientation and is much prolonged at the magic angle. T_{DE} is significantly longer throughout the plug, yet the differences between the two orientations are small. This result is expected since the RDI was eliminated by the dipolar echo sequence.

The effect of the amount of PG on the two relaxation times is shown in Fig. 2 for a bovine plug before and after trypsinization and for an average of two human control samples and two OA samples in Fig. 3. The insensitivity of T_2 to the amount of PG is clear both in the bovine and human samples. In all cases T_{DE} is prolonged relative to T_2. A significant difference between T_{DE} in the bovine PG-depleted plug relative to the intact control is observed in the surface and radial zones. T_{DE} values for the human plugs are smaller than those obtained for the bovine samples but here we also observe a significant increase in T_{DE} of the OA plugs relative to the control.

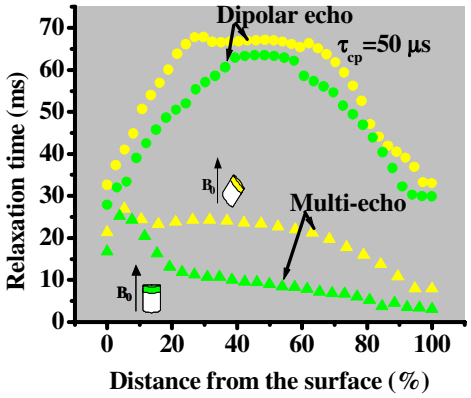

Fig. 1: T_2 and T_{DE} of a bovine articular cartilage plug. Results are given for two orientations of the plug relative to the field.

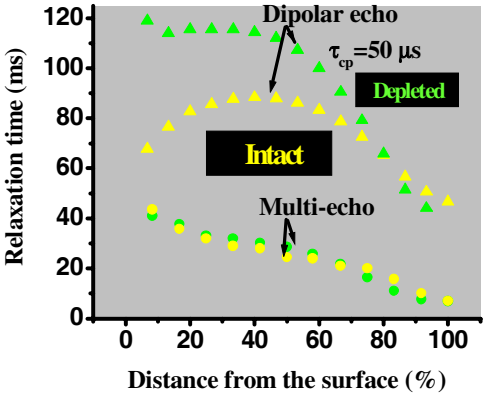

Fig. 2: T_2 and T_{DE} of an intact and PG depleted bovine articular cartilage plug.

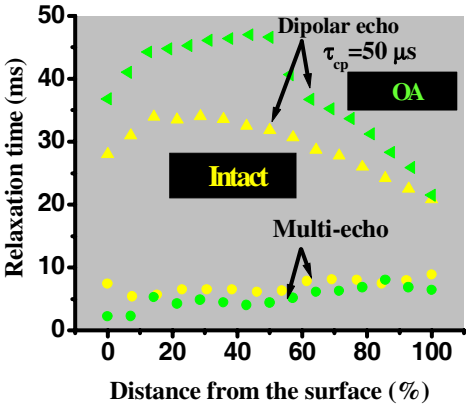

Fig. 3: Average T_2 and T_{DE} for two human control samples and two OA samples.

Discussion: The effect of PG depletion on T_2 in articular cartilage is negligible since the major contribution to T_2 is the RDI of the water protons interacting with the collagen fibers. Dipolar echo techniques refocus a substantial amount of this interaction and the relaxation times are much prolonged. At this stage the contribution of the intramolecular dipolar interaction due to isotropic reorientation and some of the contribution of the proton exchange between chemically shifted groups become dominant and are sensitive to the amounts of the PG. Dipolar echo techniques elongate the relaxation times and at the same time eliminate the orientation dependence which is a problem in cartilage imaging. The results obtained by the dipolar echo are similar but not exactly the same as those obtained by the spin locking ($T_{1\rho}$) technique (4).

References: 1.K. Muller et al., JMR 90,19 (1990). 2. U. Eliav et al., Proc. ISMRM 6th Mtg. p. 602 (1998).
3. H. Shinar and G. Navon, NMR Biomed. 19, 877 (2006). 4. A. Borthakur et al. NMR Biomed. 19, 781 (2006).