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### Quantifying NMR Relaxation Correlation and Exchange in Articular Cartilage with Time Domain Analysis

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#### Abstract

Measured nuclear magnetic resonance (NMR) transverse relaxation data in articular cartilage has been shown to be multi-exponential and correlated to the health of the tissue. The observed relaxation rates are dependent on experimental parameters such as solvent, data acquisition methods, data analysis methods, and alignment to the magnetic field. In this study, we show that diffusive exchange occurs in porcine articular cartilage and impacts the observed relaxation rates in  $T_1$ - $T_2$  correlation experiments. By using time domain analysis of  $T_2$ - $T_2$  exchange spectroscopy, the diffusive exchange time can be quantified by measurements that use a single mixing time. Measured characteristic times for exchange are commensurate with  $T_1$  in this material and so impacts the observed  $T_1$  behavior. The approach used here allows for reliable quantification of NMR relaxation behavior in cartilage in the presence of diffusive fluid exchange between two environments.

#### Keywords

Cartilage, relaxation, exchange

#### Introduction

Cartilage has been widely studied by NMR relaxation methods (1-10).  $T_2$  relaxation has been correlated to the health of the tissue with increases in observed  $T_2$  values occurring when cartilage is damaged (5). Though  $T_2$  weighted magnetic resonance imaging (MRI) has been used to track disease caused degradation of cartilage such as arthritis, the standard for clinical diagnosis of arthritis in the USA is still x-ray imaging and not MRI.

One aspect which limits MRI methods in this regard is the wide variability in reported  $T_2$  relaxation rates across studies (11) and the difficulty in connecting the observation of multiple sites, populations of different rotational and molecular mobility, to disease progression and diagnosis. Relaxation in cartilage has been shown to be composed of multiple relaxation rates

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