T1ρ Mapping of Pediatric Epiphyseal and Articular Cartilage

J. G. Cobb[1,2], and J. H. Kan[3]

[1]Biomedical Engineering, Vanderbilt University, Nashville, TN, United States, [2]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [3]Radiology and Radiological Sciences, Vanderbilt Children's Hospital, Nashville, TN, United States

INTRODUCTION

$T_{1\rho}$ imaging is based upon a measurement of the spin-lattice relaxation time in the rotating frame. $T_{1\rho}$ contrast is produced by adding a spin-lock (SL) cluster of low power on-resonance pulses before an imaging sequence. The SL cluster is generally described by the amplitude (SLA) and duration, or spin-lock time (SLT), of the applied pulses. $T_{1\rho}$ contrast may be generated by proton exchange processes on the time scale of this applied B_1 field. Thus, this type of image contrast has been used to describe low-frequency interactions between macromolecules and bulk water in tissues such as cartilage, brain, liver, and muscle. In particular, the exchange processes of articular cartilage degradation in adults have been the focus of a variety of research; however, application to children and ability to evaluate epiphyseal cartilage has not been studied. The purpose of this study is to determine feasibility of $T_{1\rho}$ mapping of pediatric epiphyseal and articular cartilage.

METHODS

Seven volunteers of age 13 ± 2 years were recruited to have $T_{1\rho}$ mapping performed at the conclusion of their clinical study. They underwent safety screening and provided written informed consent in compliance with the hospital Institutional Review Board. Subjects were imaged using a 3.0T MR scanner with an eight-channel knee coil (Philips Achieva 3T, Philips Medical Systems). Two single-slice images were acquired using a clinical 3D PDW-weighted turbo spin-echo (TSE) sequence for planning purposes. The first slice was placed in a sagittal orientation through the lateral condyle (Fig 1.a.). The second slice was placed axially through the thickest part of the patella (Fig 1.c.).

$T_{1\rho}$ contrast was generated using a SL pre-pulse developed by Avison(1). A 90 degree hard pulse was applied with phase referenced to the x-axis. This is followed by half of the SLT with a SLA of 500Hz along the y-axis. A 180 degree hard pulse is applied along y to compensate for B_1 inhomogeneity, followed by the second half of the SLT with phase reversed (-y). From there, another 90 degree hard pulse returns the $T_{1\rho}$-prepped signal to the longitudinal axis (90_{-x}), and the residual transverse magnetization is spoiled. A standard 2D TSE was then used for imaging. TSE parameters included: acquired matrix = 256 x 160, field of view = 120 x 100 mm, echo-train length = 6, TE = 10 ms, TR = 4000 ms, pixel bandwidth = ~155Hz. Spin-lock times of 20, 40, 60, and 80 ms were acquired using the same transmit and receive gains between acquisitions. Each $T_{1\rho}$-weighted scan took approximately 1 minute 20 seconds to complete, for approximately a 5 minute scan time to compute $T_{1\rho}$ maps.

Regions of interest (ROIs) were placed in non-weight-bearing regions of the sagittal slice in the epiphyseal and articular cartilage (Fig 1.a.). For the axial slice, epiphyseal and articular cartilage ROIs were placed as shown in Figure 1.c. $T_{1\rho}$ maps were generated by fitting each pixel in an ROI to a single parameter mono-exponential decay curve ($S_{(SLT)} = S_0 \exp(-SLT/T_{1\rho})$) in MATLAB (The MathWorks, Inc., Natick, MA).

RESULTS

Mean values for the ROIs generated are shown in Table 1. A student's t-test revealed a significant difference comparing epiphyseal cartilage and articular cartilage $T_{1\rho}$ values for non-weight-bearing, and patellar ROIs (See Table 1). No significant difference was found when comparing epiphyseal or articular cartilage $T_{1\rho}$ values in the two anatomical areas.

Table 1.

Mean Values	Articular Cartilage	Epiphyseal Cartilage	P-Value
Femoral Condyle	65.1 ± 15.4 ms	49.2 ± 5.2 ms	P = 0.01
Patella	67.3 ± 21.5 ms	41.5 ± 6.6 ms	P = 0.01

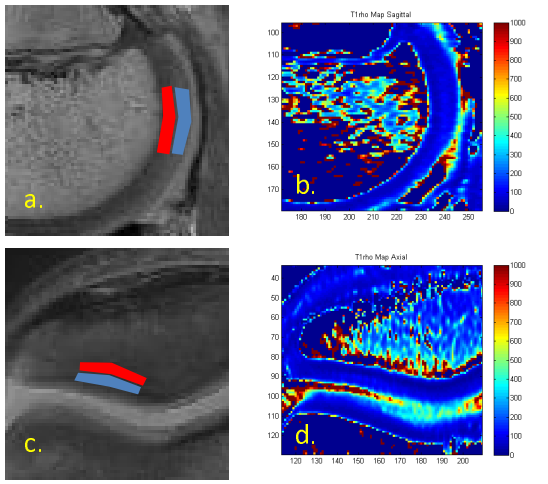

Figure 1. A representative single slice PDW-weighted sagittal (1.a.) and a T_2-weighted TSE axial planning image (1.c.) are shown with epiphyseal (red) and articular (blue) ROIs. Corresponding $T_{1\rho}$ maps are shown in Figures 1.b. and 1.d. for a single subject.

DISCUSSION AND CONCLUSIONS

$T_{1\rho}$ is a feasible method for differentiating epiphyseal and articular cartilage in children. Epiphyseal and articular cartilage $T_{1\rho}$ differences may reflect differences in water and glycosaminoglycan composition (2). Pediatric articular cartilage $T_{1\rho}$ values are somewhat longer than those of healthy adult articular cartilage reported as 62 ± 5 ms at 4T (3). The large variance in articular cartilage $T_{1\rho}$ values is most likely related to partial volume effects from non-cartilage tissue but may also reflect heterogeneity related to maturing articular cartilage since children of various ages were evaluated.

REFERENCES

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