Degeneration-induced depth-wise variation in T2 relaxation time of human patellar cartilage at 1.5T

E. Lammentausta[1], P. Kiviranta[1], J. Töyräs[2], I. Kiviranta[3], M. T. Nieminen[4], and J. S. Jurvelin[1]

[1]Department of Physics, University of Kuopio, Kuopio, Finland, [2]Department of Clinical Neurophysiology, Kuopio University Hospital, Kuopio, Finland, [3]Department of Orthopaedics and Traumatology, Jyväskylä Central Hospital, Jyväskylä, Finland, [4]Department of Diagnostic Radiology, Oulu University Hospital, Oulu, Finland

INTRODUCTION

The role of T_2 relaxation time mapping as a surrogate marker for cartilage degeneration has previously been investigated in several studies. In vivo studies with human subjects have revealed that T_2 increases in osteoarthritis [1] and with age [2]. Experimental studies have revealed both an increase [3-5] and a decrease [6] in T_2 after enzymatic degradation. Experimental models with specific enzymatic treatments and animal cartilage, however, may not mimic actual changes taking place in disease. Therefore, we investigated in vitro the depth-wise changes in T_2 relaxation time of human cartilage with different levels of histologically confirmed degeneration at a clinically applicable field strength.

METHODS

Patellae of human cadavers (N=14, 12 male, 2 female, age 55 ± 18 years) were equilibrated overnight in 0.5mM Gd-DTPA(2-) solution. It has been previously shown that, at low contrast agent concentrations, the effect on T_2 relaxation time of cartilage is minimal [7]. For 1.5 T MRI measurements, a clinical 1.5T scanner and a 3" receiving coil were used (GE Signa 1.5T, GE Healthcare, Milwaukee, WI). Articular surface of intact patellae was oriented parallel to B_0 to emulate clinical patient positioning. Six locations of interest were defined to cover the entire articular surface of each patella. T_2 maps were calculated from multi-slice multi-echo spin echo experiments (GE prototype sequence with improved slice profile, TR=1000ms, 8 TEs between 10.3-82.4ms, ETL=8, 3-mm slice thickness, 0.31 mm in-plane resolution at room temperature). Depth-wise T_2 profiles were calculated by averaging ten pixels along the cartilage surface to match the slice thickness. For samples with a histologically verified superficial zone (see below), the length of the profiles was normalized to unity and the profiles were resampled for further depth-wise comparison.

Blind-coded safranin-O-stained histological sections from the aforementioned cartilage samples were graded for degeneration using a modified Mankin score system [8] independently by three of the authors. As the samples were detached from subchondral bone, the integrity of the tidemark could not be evaluated. Depth-wise profiles of angle of main orientation calculated from polarized light microscopic images were used to exclude samples without a visible superficial collagenous zone. The samples were divided into three groups according to their Mankin score (I (0<MS<3.3, N= 12), II (3.3<MS<6.7, N=20) and III (6.7<MS<9, N=10)), and averaged profiles were calculated for each group. The significance of the difference in T_2 values of different groups was assessed using Kruskal-Wallis test.

RESULTS

The samples studied represented relatively early stages of cartilage degeneration, as evidenced by the histological sections (Fig. 1). As compared to the group of least degeneration (group I), group II showed a trend toward prolonged T_2 values to approximately 10% of tissue thickness (Fig. 2). Group III showed a significant increase of T_2 to approximately 50% of tissue thickness as compared to groups I and II. For the remaining 50% the depth-wise profiles for the three groups showed similar T_2 values. The most superficial layer of articular cartilage was not visible in the T_2 profiles because its thickness is typically beyond the resolution of clinical MRI devices. Due to large deviations, there were no significant differences between the groups at any point along depth-wise profile, however the p-values were considerably smaller near the surface (Fig. 2).

DISCUSSION

T_2 relaxation time of superficial articular cartilage shows a trend toward higher values among more degenerated cartilage samples, and the T_2 elevation extends deeper with increasing degeneration. Previously, osteoarhritic cartilage samples were evaluated using T_2 with parallel histology [9]. The results were mostly similar with increased T_2 values in the most degenerated cartilage samples but with decreasing T_2 values in moderately degenerated samples, a finding that could not be reproduced in the present study.

The observed T2 changes were not quite statistically significant, yet revealed a trend toward higher T2 values with degeneration. It is noteworthy that the histological scoring system used assesses tissue properties other the those of the collagen network, and consequently probes different aspects of the tissue than T2.

The evaluation of the cartilage surface was conducted using polarized light microscopy to ensure that the most superficial layer of the samples was present and had not worn out due to the degenerative processes. This enabled a reliable normalization of data including the superficial cartilage. The present results suggest that tissue with an intact surface and characteristic orientation of collagen fibrils may have undergone degenerative changes that are reflected by an elevation of T_2 relaxation time. While decreasing T_2 relaxation has previously been reported in an enzymatic model of degeneration [6], we were unable to reproduce this finding with degenerated native human tissue.

In the present measurements, the articular surface was oriented parallel to the B_0 field to emulate the in vivo conditions. In general, the angular dependence of the dipolar interaction at different joint surfaces has to be considered [10]. The cartilage zone with collagen fibrils oriented parallel to the B_0 field will experience weaker dipolar interaction, and therefore T_2 in different areas may show variations in sensitivity to degenerative changes. Thus, further work is required to investigate the sensitivity of T_2 to degeneration at different orientations to B_0 at different cartilage depths.

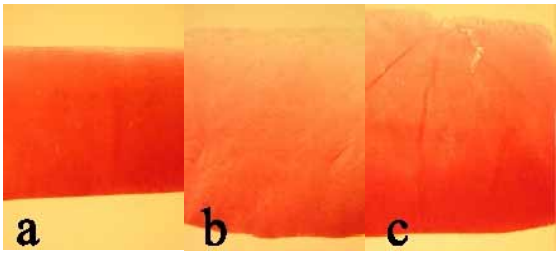

Figure 1. Representative human patellar cartilage samples for a) group I, b) group II and c) group III.

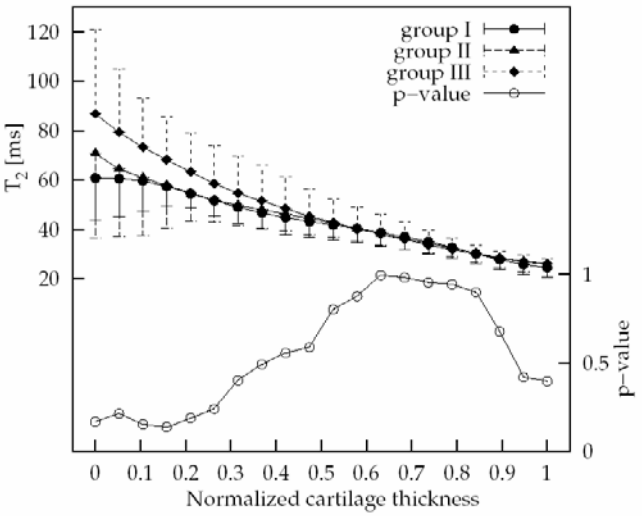

Figure 2. Resampled depth-wise T_2 profiles for samples with different stages of degeneration (groups I-III). The articular surface is to the left. Degeneration related prolongation of T_2 becomes more prominent, yet not statistically significant, and extends deeper into the tissue with increasing degeneration.

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