INTRODUCTION

With the improvement in medical and surgical treatment of cartilage injuries, magnetic resonance imaging (MRI) has played an ever-increasing role in the diagnosis and monitoring of cartilage degeneration. Recent studies have shown the potential of MR parameters to reflect changes in biochemical composition of cartilage with early cartilage degeneration or osteoarthritis (OA). These techniques include $T_1$ and $T_2$ quantification (1,2). These relaxation times provide quantitative analysis of cartilage condition instead of traditional qualitative description of cartilage pathology. The goal of our study is to develop a robust in vivo method of quantitative cartilage imaging using high field MRI. In this study, healthy controls and OA patients were scanned at 3T using the developed $T_1$-$T_2$ sequence as well as $T_1$ mapping and anatomic MR images. The goals were 1) to examine the ability of $T_1$ and $T_2$ relaxation times to distinguish between patients with OA and normal controls; 2) to investigate the relationship between $T_1$ and clinical evaluation by radiography and routine clinical MR images.

METHODS

Eight healthy controls (6 male and 2 female, mean age 40, range 28-74 years) and eight OA patients (5 male and 3 female, mean age 55, range 32-72 years) with clinical OA symptoms and radiologic findings of cartilage degeneration were studied. All MR exams were implemented on a 3T GE MR scanner using a quadrature knee coil. The acquisition parameters for the $T_1$-$T_2$-weighted imaging sequence were: FOV=16cm, effective in-plane spatial resolution = 0.6 x 0.6 mm, slice thickness = 3 mm, skip = 1 mm, TR/TE = 2000/5.8 ms, TSL = 20/40/60/80 ms, spin lock frequency = 500 Hz. The imaging protocol also included sagittal and axial 3D water excitation high-resolution spoiled gradient-echo (SPGR) imaging fat-saturated $T_1$-weighted fast spin-echo (FSE) images, and spiral $T_2$ quantification sequence (TR/TE = 2000/6.7, 12, 28, 60 ms, all other prescription parameters are the same as the $T_1$ sequence). The axial $T_1$-$T_2$-weighted and $T_1$-weighted images were prescribed on sagittal SPGR images, covering regions from the top of the patellar cartilage to the femoral-tibial cartilage.

All the radiographs and clinically diagnostic MR images were reviewed by a radiologist. The radiographic findings were scored according to the Kellgren-Lawrence (KL) scale. The MR images were analyzed regarding cartilage thinning (1: <50%; 2: >50%; 3: full), osteophytes, bone marrow edema, meniscal tears and other soft tissue abnormalities. Five compartments were defined: the medial and lateral femoral condyle, the medial and lateral tibia and patella. Cartilage was segmented semi-automatically in sagittal SPGR images. The cartilage volume and average thickness for each of the five compartments were calculated. The $T_1$-map was reconstructed by fitting the $T_2$-weighted images pixel-by-pixel to the equation $\rho(TSL) = \exp(-TSL/T_1)$. $T_1$ and $T_2$ maps were aligned to the axial SPGR images. 3D cartilage contours were generated based on axial SPGR images and overlaid to the registered $T_1$ and $T_2$ maps. Mean, standard deviation, and median $T_1$ and $T_2$ values were calculated for different regions of cartilage, as well as for the cartilage as a whole. A non-parametric rank test was used to compare average $T_1$ and $T_2$ values between controls and patients. A Spearman rank correlation was performed to study the relationship between the average $T_1$ and $T_2$ values within cartilage. The effect size was calculated to compare the discrimination power of these two parameters as: $\text{effect size} = \Delta mean/SD$, where $\Delta mean$ is the mean difference between control and OA, and SD is the pooled standard deviation of these two groups.

RESULTS

The cartilage volume and average thickness were not significantly different between controls and OA patients for this population. Both average $T_1$ and $T_2$ increased significantly from controls to OA patients ($P=0.0003$ and $P=0.0104$ respectively). $T_1$-$T_2$ maps for a healthy volunteer and a patient with OA was shown in Fig. 1. The effect size was 2.78 and 1.78 for $T_1$ and $T_2$ respectively, showing a higher discrimination power of $T_1$ values. Average $T_2$ correlated with $T_1$ significantly ($R=0.368, P<0.001$). $T_2$ values were correlated with $T_1$ significantly (Table 1). These relaxation times provide quantitative analysis of cartilage condition instead of traditional qualitative description of cartilage pathology. The goal of our study is to develop a robust in vivo method of quantitative cartilage imaging using high field MRI. In this study, healthy controls and OA patients were scanned at 3T using the developed $T_1$-$T_2$ sequence as well as $T_1$ mapping and anatomic MR images. The goals were 1) to examine the ability of $T_1$ and $T_2$ relaxation times to distinguish between patients with OA and normal controls; 2) to investigate the relationship between $T_1$ and clinical evaluation by radiography and routine clinical MR images.

DISCUSSION

$T_1$ and $T_2$ values were significantly different between controls and OA patients while cartilage volume and thickness were not, supporting these relaxation times are valuable in assessing OA, in particularly at early stages. $T_1$ has a higher effect size than $T_2$, showing $T_2$ may be a more sensitive indicator of cartilage degeneration than $T_1$. $T_1$-$T_2$ values were correlated with radiologic findings based on radiographs and anatomic MR images. A larger cohort of age-matched controls and patients with different stages of OA will be studied in the future and changes of $T_1$-$T_2$ relaxation time in the longitudinal follow-up in patients with OA and volunteers will be analyzed. In addition to the average relaxation time in the whole cartilage, spatial distribution of $T_1$-$T_2$ relaxation time will also be examined to identify focal lesions.

REFERENCES


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