Assessment of T1ρ and T2 mapping as biomarkers of denaturalization in articular cartilage with osteoarthritis: comparison with pathological results after total knee replacement

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Introduction

T1ρ and T2 mapping have been investigated as useful quantitative imaging techniques to assess the chemical properties of articular cartilage [1-4]. It has been reported that there are significant correlations between these maps and symptoms or radiographic signs in osteoarthritis (OA) patients [3,4]. T1ρ mapping is superior to T2 mapping for differentiating OA patients from healthy subjects [4]; however, the correlations between mapping and pathological examinations have not been investigated. In this study, we retrospectively compared T1ρ and T2 mapping with pathologically confirmed results in OA patients. We analyzed the ability of each mapping technique to detect an early stage of denatured articular cartilage and the correlations between each type of mapping and the severity of denaturalization.

Materials and Methods

Fifteen patients with OA of the knee (age range = 67–86, mean = 74.1 years, M:F = 2:13) were scanned on a 3-Tesla MR system using an 8-channel phase-array knee coil. 2D-Saggital T1ρ and T2 maps were obtained 1-2 weeks before total knee replacement. T1ρ maps were calculated from T1ρ-prepared images using the steady state free precession (SSFP) technique (TR/TE = 4.7/2.4 ms, FOV = 140 x 140 mm, matrix = 320 x 320, slice thickness = 3 mm, TSL = 1/20/40/60/80 ms, spin-lock pulse frequency = 500 Hz, number of slices = 26). T2 maps were also calculated from T2-weighted images using the TSE technique (TR = 2693 ms, TE = 16/32/48/64/80 ms, FOV = 140 x 140 mm, matrix = 320 x 320, slice thickness = 3 mm, number of slices = 20). After the surgery, specimens of the femur and tibia were diagnosed by an orthopedic surgeon and a severity map of denatured articular cartilage was recorded for each specimen referring to previously reported methods (Grade 0: normal, 1: mild, 2: moderate, 3: severe, 4: subchondral bone exposure) [5]; however, Grade 4 was excluded from this study because of severe thinning of the articular cartilage. Independently, T1ρ and T2 values, and the thickness of all layers of articular cartilage were calculated after regions of interest (ROIs) were drawn on maps by radiologists using positional information from pathological results. Those values of each grade were statistically compared using the Mann-Whitney U test. $p < 0.05$ was considered significant. Additionally, Spearman's rank correlation coefficients between the T1ρ and T2 values and thickness, and the severity of denaturalization were analyzed.

Results

Eighty-nine regions (Grade 0, 1, 2 and 3 = 16, 22, 34 and 17 regions) were analyzed. Means and standard deviations of T1ρ and T2 values and the thickness of each grade are summarized in Table 1. On the T1ρ map, Grade 1, 2 and 3 showed significantly higher values than Grade 0 ($p < 0.05$), but on the T2 map, there were no significant differences between Grade 0 and other grades. Regarding the thickness of articular cartilage, there were significant differences between Grade 3 and other grades but no significant differences among Grade 0,1 and 2. Both T1ρ and T2 maps showed significant positive correlations to the severity of denatured articular cartilage (T1ρ: $\rho = 0.60$, T2: $\rho = 0.30$, respectively, $p < 0.01$), but there was no correlation between thickness and the severity of denaturalization.

Table 1 Means and standard deviations of T1ρ and T2 values, and thickness of articular cartilage

Grade	T1ρ value [ms]	T2 value [ms]	Thickness [mm]
Grade0	40.36 ± 3.95	39.68 ± 12.40	2.59 ± 0.59
Grade1	44.95 ± 4.89 [1)]	39.45 ± 6.77	2.67 ± 0.64
Grade2	47.94 ± 4.76 [2)]	45.37 ± 10.88 [4)]	2.67 ± 0.56
Grade3	54.84 ± 11.51 [3)]	48.09 ± 11.95 [4)]	1.82 ± 0.78 [3)]

Significant difference from Grade 0 [1)]
Significant difference from Grade 0 and 1 [2)]
Significant difference from Grade 0, 1 and 2 [3)]
Significant difference from Grade 1 [4)]

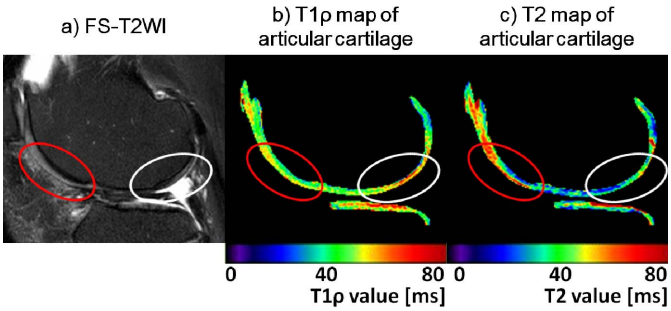

Figure 1. a) FS-T2WI, b) T1ρ and c) T2 maps of articular cartilage of a representative case with Grade 1(white circle) and Grade 2(red circle) severities of denatured articular cartilage. Both T1ρ and T2 maps showed prolonged values at these denatured regions.

Discussion

T1ρ and T2 mapping are useful to detect mild and moderate denaturalization prior to the thinning of articular cartilage. In particular, T1ρ mapping is superior to T2 mapping to detect the early stage of denaturalization. Both T1ρ and T2 mapping are helpful to assess the severity of denaturalization, but T1ρ mapping may be more sensitive than T2 mapping.

References

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