Comparison of 3T-magnetic resonance imaging T1rho values and T2 values of the menisci in healthy young subjects

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Purpose

Magnetic resonance imaging (MRI) technology has improved during the past decade and now allows for precise noninvasive visualization of joint structures; however, conventional MRI techniques can not yet sufficiently detect or quantify early changes of osteoarthritis such as disruption or alteration of knee structure. Non-invasive study of the effects of and structural changes due to osteoarthritis of the knee is imperative for early detection as well as effective diagnosis and treatment of osteoarthritis. Many new quantitative MRI methods, including dGEMRIC, T2 mapping, and T1rho measurement, have been proposed for evaluation of early changes of macromolecular structures[1]. T1rho MRI is an attractive technique that can be used to non-invasively evaluate biochemical changes in knee cartilage[2-5], spine discs[6], and liver fibrosis[7].

Many articles have reported that T1rho values are very sensitive to proteoglycan loss and degeneration in knee articular cartilage[2-3]. However, because the meniscus contains mainly water and collagen, the meniscus has a relatively low proteoglycan concentration[8], and little is known about how T1rho values change in the meniscus because of proteoglycan degeneration.

Using dGEMRIC MRI, Krishnan showed that the degeneration process of proteoglycan may be similar in the meniscus and in cartilage[9]. Rauscher reported promising results using the T1rho technique to quantify degeneration changes in the meniscal matrix[10]. On the other hand, Tsai showed that there was no difference in T2 values between the anterior and posterior horn in both the medial and lateral meniscus[11]. Wang showed that there are some differences between knee cartilage and the meniscus in the areas with elevated in T1rho values, and hypothesized the possibility of differences in the degeneration process between the meniscus and cartilage[5].

The white, avascular deep zone occupies the central part of the meniscus, and the red, vascular surface zone occupies the more peripheral 10-33% of the meniscus[12]. Tears in the red zone are more likely to heal than tears in the white zone because of the rich vascularity of the red zone[8]. Thus, proteoglycan degeneration in the red zone may be more likely to be repaired than the proteoglycan degeneration in the white zone. Because the red zone and the white zone of the meniscus have different concentrations of proteoglycans and healing abilities, 1) T1rho values may not be elevated in the red zone compared to the white zone, and 2) meniscus regions where T1rho values are elevated do not correspond to the weight-bearing meniscus regions (for example, the medial posterior horn).
The aim of the present study was to show the difference of T1rho values and T2 values between the white zone and the red zone of medial and lateral menisci.
Methods and Materials

Twenty-two asymptomatic females (mean age ± standard deviation (SD), 34.0 ± 8.4 years; range, 22 to 46 years) were examined at 3.0 T using T1rho mapping and T2 mapping. Inclusion criteria were good health (according to medical history, physical examination, and clinical laboratory data); normal body mass index (from 20 to 24 kg/m²); and absence of a contraindication to MRI. Other inclusion criteria included a Kellgren-Lawrence grade of 0, absence of osteoarthritis on MRI and x-ray of both knees, intact function and full strength of the knee joint, and no history of chronic or frequent knee pain. After the nature of the procedure was explained, all participants provided their informed consent to participate in the study. All protocols were approved by the Committee on Human Research of our institution. Because all subjects were asymptomatic, there was no surgery performed nor pathological histology obtained. No weight-bearing equipment or positions were used. The right knee of each patient was scanned for both T1rho values and T2 mapping under no-load conditions at 30 degrees of flexion.

All MR exams were implemented at 3.0 T (Philips Achieva QD R.3.1.1.2. MR scanner, Koninklijke Philips Electronics N.V., Eindhoven, The Netherlands) using an 8-channel SENSE knee coil. Parameters for sagittal T1-weighted fast spin echo (SE) imaging were: repetition time (TR)/echo time (TE) = 600/10 ms; field of view (FOV) = 15 cm; matrix = 512x512; bandwidth = 230 Hz/pixel; and number of excitations (NEX) = 1. Parameters for sagittal T2 mapping were: TR = 2671 ms; TE = 16, 32, 48, 64, 80, and 96 ms, FOV = 200x200 mm, matrix=256x256; thickness = 4.0 mm, gap = 0 mm; 20 slices, echo train length (ETL) = 6, and scan time = 22 min 52 s. Parameters for proton density weighted SPIR images were: TR/TE = 4000/20 ms, FOV = 15 cm, matrix = 512x512, bandwidth = 289.7 Hz/pixel, thickness = 3 mm, gap = 1 mm, number of slices = 24, ETL = 6, and NEX = 1.

Sagittal T1rho-weighted images were obtained using the spin-lock technique and spiral image acquisition. The following acquisition parameters were used for 3D-balanced-TFE: TR/TE = 4.8/2.4 ms, 20 interleaves/slice, 4096 points/interleaf, FOV = 15 cm, matrix = 256x256, effective in-plane spatial resolution = 0.58x0.58 mm, slice thickness = 4 mm, number of slices = 20, time of spin-lock (TSL) = 1/10/20/30/40 ms, flip angle = 50 degrees, spectral presaturation of inversion recovery (SPIR) fat saturation with a spin-lock frequency = 759.5 Hz/pixel, and a total acquisition time of 12 min 42 s. MRI scans were performed in one continuous session without removing the subject from the scanner. Measurements were conducted in the evening between 5 and 7 p.m. T1rho maps of hyaline cartilage were reconstructed by fitting the T1rho-weighted image intensity pixel-by-pixel with Eq. 1 (see below) using an in-house Levenberg-Marquardt mono-exponential fitting algorithm written in C:
S(TSL) \mu \exp(-TSL/T_{1\rho}) (1)

Where TSL is the time of spin lock, and S is the signal intensity in a T1rho-weighted image with a certain TSL. MR images were transferred to a Dell workstation (Dell Inc., Round Rock, TX, USA) for off-line quantification of cartilage T1rho relaxation time.

The meniscus was evaluated by trained observers who were blinded to subject identity. Sagittal proton density-weighted fast spin echo images with fat saturation were acquired in order to separate the white zone and the red zone of anterior and posterior meniscus.

The red zone of meniscus corresponds to the outer half of the anterior and posterior horns of the meniscus. The white zone of the meniscus was defined as half of the inner red zone (Fig. 1). Pearson's correlation coefficient and simple linear regression analysis were used to assess the relationship between age and T1rho values and T2 mapping in each meniscus zone. Mean and SD of T1rho values and T2 mapping were calculated in each of the meniscus compartments in all subjects. Paired t tests were employed to compare the mean intra-group T1rho values and T2 mapping within all defined sub-compartments. P values < 0.05 were considered statistically significant. All analyses were performed using the JMP8.0 (SAS Institute, Cary, NC, USA) and SPSS16.0 statistical package (SPSS, Chicago, IL, USA).
Fig. 1: Figure 1 Meniscus segmented sub-compartments - redzone of anterior horn (1), white zone of anterior horn (2), redzone of posterior horn (4) and white of posterior horn (3) - displayed on a T2 mapping image.

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Results

In the anterior and posterior horn of the lateral meniscus, there were no significant differences in T1rho values or T2 mapping. However, significantly elevated T1rho values were found in the anterior red zone compared to the posterior red zone, and in the anterior white zone compared to the posterior white zone.

At the medial meniscus, both in the anterior and posterior horn, there were no significant differences in T1rho values or T2 mapping when comparing the red zone and the white zone. However, significantly elevated T1rho values were found in the anterior red zone compared to the posterior red zone, and in the anterior white zone compared to the posterior white zone (Fig. 2).

Assessment of T2 mapping for these zones showed that there was a significant difference between the lateral anterior red zone and the lateral posterior red zone (Fig. 3). In the red zone and the white zone of the medial posterior horn of the meniscus, T1rho values had a moderate yet significant positive correlation with age. In the red zone of the medial anterior horn of the meniscus, T1rho values correlated significantly positively with age. In the lateral meniscus, both in the anterior and posterior horn, there were no significant correlations between T1rho and age. T2 mapping correlated significantly positively with age only in the white zone of the medial posterior horn of the meniscus (Table 1).
**Fig. 2:** Figure 2 Bar chart showing the mean T1rho values for the red and white zone of the anterior and posterior horns in the medial and lateral menisci.

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**Fig. 3:** Figure 3 Bar chart showing the mean T2 mapping values for the red and white zone of the anterior and posterior horns in the medial and lateral menisci.

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Table 1: Comparison of the T1rho and T2mapping of the red and white zone of the anterior and posterior horns in the medial and lateral menisci.

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Conclusion

T1rho may be more sensitive than T2 mapping for detection of early degeneration of the meniscus.
References


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Personal Information

Conflicts of interest

None declared.

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