Regional difference of diverse zones in human menisci investigated by quantitative T2 measurements

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Introduction

Quantitative T2 measurement of knee cartilage has been recently applied to detect the cartilage degeneration due to osteoarthritis (OA). In addition to hyaline cartilage, the menisci play a critical role in the normal biomechanics of the knee joint in, for example, load bearing, load distribution, and so forth. There are some papers which show the T2 value of menisci ranging from 5 – 8 msec at 1.5T [1]. However, the orientation of collagen fibers in menisci and the components of menisci are variable in different locations. According to the magic angle effect, the signal intensity and T2 value of menisci have a variety of appearances depending on the fiber orientations. When $3\cos^2\theta-1 = 0$ ($\theta=55^0$, 125^0, etc.), where θ is the angle between the fiber orientations and the magnet field B_0, the dipolar interactions are minimized leading to increase T2 values and hence high signal intensity [2]. Therefore, the T2 value measured in clinical settings should also be regionally variable. The purpose of this study is to determine the T2 distributions within different zones of the menisci.

Methods

Six normal subjects were enrolled in this preliminary study. All of them were imaging in supine position in a 3.0T MR system (achieva, Philips Medical System). These images were acquired with an eight-channel knee coil using fast spin echo sequence with TR = 2000ms, TE = 7.4/8.5/9.9/11 ms, number of slice = 6, slice thickness = 1 mm, matrix size = 560×560, inplane resolution = 0.29×0.29, acquisition time = 3m30s for each TE. In order to derive the T2 value with sufficient accuracy, partial echo with fat suppression was used to decrease the echo time for water protons. The T2 maps were calculated on a pixel-by-pixel basis by fitting the echo time data and the corresponding signal intensity to a single exponential relaxation model. On the color-coded T2 map, low T2 value was represented with the red color and the high T2 value with green or blue color. T2 values were investigated in each sagittal image for the menisci anatomically divided into the red (vascular) and the white (avascular) zones [3]. The white zone was further categorized according to the two main directions of collagen fibers in menisci with fibers running in a radial direction in the internal circumference, and that in a circular direction in the external circumference [4]. Hence, three regions of interest (ROIs) were manually defined including red zone (RZ), white zone with radial collagen fibers (WZ_r), and white zone with circular collagen fibers (WZ_c)(Fig.1).

Results

A proton density weighted sagittal image of the menisci is shown in Fig.2. We can clearly distinguish the red zone (higher signal intensity) of meniscus from the white zone (lower signal intensity) on the image (as the arrows point). The T2 map shown in Fig.3 shows the same information. In addition, the different T2 values in the white zone of menisci reflect the different directions of fibers due to the magic angle effect. ROI evaluations of the T2 values yielded 52.2661±12.0644ms for the red zone, 5.8844±0.6453ms for the white zone with radial fibers, and 4.1821±0.4847ms for the white zone with circular fibers, respectively. Differences between any two groups were statistically significant ($P < 0.0001$).

Discussion

The present findings indicated the feasibility of high-resolution MR imaging in regional T2 analysis for the menisci, with which a T2 template of the menisci could be established gradually. The highest T2 value of the red zone is likely dominated by the abundant blood vessels within this vascular zone. On the other hand, the difference of T2 value between radial fibers and circular fibers in white zone likely reflects the diverse orientations of collagen fibers showing different degrees of the magic angle effects. Since changes in T2 values of the menisci are related to disruption of cartilage architecture and water content [5], measurements of T2 values may reflect flux of water content or changes of collagen fiber orientations to a different degree in different zones in the menisci. We conclude that quantitative T2 measurements help recognizing the functions of the menisci, with potential in clarifying the relationships among menisci, hyaline cartilage, and osteoarthritis.

References

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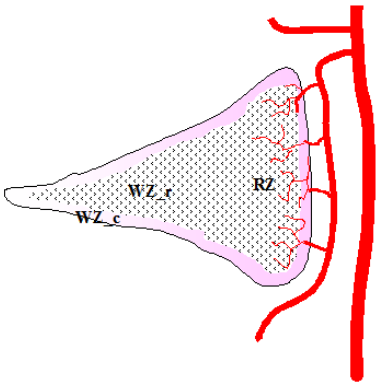

Fig.1 Definition of ROIs in the menisci

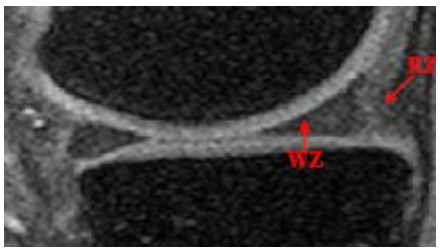

Fig.2 Sagittal image of the menisci

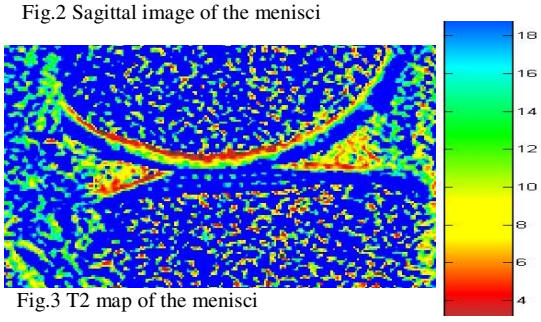

Fig.3 T2 map of the menisci