dGEMRIC of the medial meniscus in patients after matrix-associated autologous chondrocyte transplantation (MACT) of the medial femoral condyle

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Purpose

Delayed Gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) is an established method to quantitative evaluate the glycosaminoglycan content of articular cartilage [1 - 3] especially of the knee [3, 4].

Along with articular cartilage the menisci of the knee joint are also important for load distribution and attenuation across this joint [5, 6]. Loss of integrity of the menisci has been associated with osteoarthritis of the knee joint [7 - 9].

The menisci of the knee are fibrocartilaginous [10] with a lower proteoglycan content of the extracellular matrix than hyaline cartilage [11] and predominately collagen type 1 contrary to type 2 as in hyaline cartilage [12]. These differences in composition will result in different optimal imaging parameters of magnetic resonance imaging. Still, the purpose of this study was to evaluate a standard dGEMRIC protocol for cartilage as regards the medial meniscus in healthy volunteers versus patients after a matrix-associated autologous chondrocyte transplantation (MACT) of the medial femoral condyle.
Methods and Materials

Subjects:

a: Patients' group: 14 patients had their one-year follow-up examination after a matrix-associated chondrocyte transplantation (MACT) on the weight-bearing zone of their femur condyles. A MACT procedure is used to treat an International Cartilage Repair Society (ICRS) grade III or IV lesion with a size between 2 and 12 cm², located ideally on either the femoral condyle or the trochlea [13]. The fourteen patients consisted of seven females and seven males with a mean age of 33.5 years (range 20 - 53y) and a mean BMI of 24.5 (range 20.7 - 30.5).

b: Healthy volunteers' group: Ten subjects with no history of knee injury and no clinical signs or symptoms of OA, consisting of three females and seven males with a mean age of 27.8 years (range 20 - 35y) and a mean BMI of 22.2 (range 18.4 - 27.2).

Image acquisition:

A dGEMRIC protocol consists of a quantitative T1 mapping performed both prior to and after intravenously applying Gd-DTPA²⁻. After administering a bolus of 0.2 mmol of contrast agent per kilogram of the patient's body weight [4], patients exercised their knees by walking for about twenty minutes to optimize the distribution of the contrast agent for the post contrast imaging, which took place approximately 90 minutes after contrast injection [3]. MR imaging was performed on a 3.0 Tesla MR scanner with an eight-channel phased-array knee coil. The quantitative T1 mapping employed a sagittal pre- and postcontrast variable flip angle 3D GRE sequence with the following parameters: TR 15ms, TE 3.94ms, flip angle of both 4.6° and 26.1°, image matrix 320x320, field of view 160x160mm, slice thickness of 3mm and an acquisition time of 1 minute and 53 seconds. The morphology of the meniscus was analyzed with a sagittal PD-weighted TSE sequence (TR 2670ms, TE 38ms, image matrix 512x512, field of view 120x120mm, slice thickness 2mm, acquisition time 7 minutes and 53 seconds).

Image and data analysis:

The morphologic MR sequence was analyzed for signal changes within the meniscal substance as sign of degeneration or tears of the horns of the medial meniscus on a slice-by-slice basis according to the corresponding slice of the T1 map.

The T1 values of the meniscus were assessed separately for the anterior and the posterior horn with regions of interest (ROIs) on every single slice. These T1 values represent the arithmetic mean of the T1 values in a given ROI. To assign the ROIs anatomically correct, they were first drawn on an image of the T1 sequence and then...
copied to the corresponding image of the T1 map. To avoid partial volume artifacts we excluded the body of the meniscus from evaluation. We considered only those parts of the menisci with the same signal intensity as the more centrally parts for ROIs.

We calculated the delta relaxation rate ($\Delta R_1$) is the difference of the relaxation rate $R_1 = 1/T_1$ (in 1/sec) of the pre-contrast and the post-contrast map [3, 14]. The $\Delta R_1$ values are proportional to the concentration of Gd-DTPA$^{2-}$ in a given tissue [15] and account for potential differences of the T1 (ms) in the precontrast image acquisition.

**Statistical analysis**

All data were analyzed without calculating arithmetic means of the data sets of the subjects. We performed ANOVA with Bonferroni’s multiple comparison test with a two-tailed $p$-value of less than .05 considered as statistically significant. Receiver operating characteristics (ROC) analysis was used to estimate the diagnostic performance of the $\Delta R_1$ values with area-under-curve values with corresponding 95% confidence intervals.
Results

We calculated a total of 480 #R1-values of the medial meniscus in both our subject groups together.

#R1 differed significantly with a p value < .001 between the two groups both for the anterior and posterior horns (Table 1 on page 7). Mean #R1 was higher in the patient group for both the anterior and the posterior horn (Illustration 1 on page 7).

ROC analysis resulted in an area-under-curve of 0.7921 for the anterior horns and 0.8968 for the posterior horns, respectively (Illustration 2 on page 8).

Image 1 on page 9 shows the PDw image as well as the pre- and postcontrast T1 map of a healthy volunteer contrasted by the corresponding images of a patient after MACT.
Fig. 0: Table 1 ANOVA

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**Fig. 0:** Illustration 1: Box and whiskers (Min to Max) graph and column statistics of the anterior and posterior horn of the medial meniscus of both the healthy volunteers and the patients after MACT

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Fig. 0: Illustration 2: ROC curve and statistical analysis of the anterior and posterior horn of the medial meniscus

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Fig. 0: Figure 1: The left column shows a healthy volunteer, the right column a patient after MACT. The top row contains the PDw images, the middle row the corresponding T1 map pre-contrast, and the bottom row the corresponding T1 map post-contrast. The color-coded maps show the T1 (ms) and have the same window width (1400) and window level (700) for both pre- and post-contrast images. Please note the small difference of T1 (ms) between left and right image for the pre-contrast maps, but the large difference of T1 (ms) for the post-contrast maps. Post-contrast T1 (ms) is lower in the patient although the corresponding PDw image has no signal changes in the meniscal substance.

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Conclusion

dGEMRIC can differentiate the medial meniscus in healthy knees from non-meniscal preinjured knees even if the meniscus was diagnosed as normal with morphological MR. The estimated diagnostic performance shows a promising potential for dGEMRIC as a means to evaluate the meniscus.
References


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