Reproducibility of Patellar Cartilage Volume and Thickness at 3.0T: 3D-FLASH vs. 3D-TrueFISP

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Introduction:

Osteoarthritis (OA) which is characterized by a progressive loss of articular cartilage is the single largest cause of disability in the elderly [1]. Magnetic resonance imaging (MRI) at 1.5T has proven a valuable technique to monitor osteoarthritis as it is possible not only to visualize cartilage changes by MRI but additionally to assess quantitative parameters of disease progression such as cartilage volume and thickness. Especially new treatment techniques, e.g. autologous cartilage or chondrocyte transplantation, and the development of structure-modifying drugs highlight the need for valid and robust MR techniques for evaluation of therapy success. At 3.0T, to date, there is few experience in this field. Therefore the purpose of this study was to compare the reproducibility of patellar cartilage volume and thickness measurements with a previously validated 3D-FLASH sequence [2] and an optimized 3D-TrueFISP sequence which has not been used for assessment of cartilage volume on a 3.0T scanner so far.

Materials and Methods:

We examined the patellar cartilage of the right knee joint of 6 healthy volunteers aged between 25 and 30 (mean = 26.5) years. In order to avoid load-induced compression of the cartilage [3] the volunteers were asked to rest physically for about 1 hour prior to imaging. The MR measurements were performed on a 3.0T whole-body imager (Magnetom Trio, Siemens Medical Solutions, Germany) using a commercial transmit-receive extremity coil. The whole patella was covered by 40 axial slices (thickness = 1.5 mm), the in-plane resolution was chosen 0.31^2 mm^2. Image data were acquired with a 3D-FLASH water excitation sequence (TR/TE = 12.4/5.3 ms, flip angle = 10°, bandwidth = 130 Hz/pixel) and a 3D-TrueFISP water excitation sequence (TR/TE = 8.9/3.2 ms, flip angle = 28°, bandwidth = 290 Hz/pixel).

To assess the reproducibility of the cartilage volume and thickness measurements, we acquired 3 consecutive data sets of each volunteer for both sequence techniques, the knee joints being repositioned between the replicated examinations. In all image data the patellar cartilage was delineated by an interactive segmentation routine [4,5]. Cartilage volume, mean and maximum thickness were calculated with a previously described algorithm [6]. The intra-individual reproducibility was determined as coefficient of variation (CV, given in %) of the 3 consecutive measurements. The average reproducibility was determined as the root mean square average of the CVs of the 6 volunteers. Finally, the inter-individual variability of cartilage volume and thickness was estimated by computing the mean value and the relative standard deviation across the 6 volunteers.

Results and Discussion:

The patellar cartilage volume varied from 3.4 to 6.3 ml (FLASH) / 3.1 to 6.0 ml (TrueFISP). The intra-individual reproducibility ranged from 0.6 to 2.5% (FLASH) / 0.9 to 6.9% (TrueFISP), resulting in an average reproducibility of 1.8% (FLASH) / 4.4% (TrueFISP). The inter-individual variability of the patellar cartilage volume was 24.6% (FLASH) / 24.5% (TrueFISP).

The mean patellar cartilage thickness varied from 2.1 to 2.8 mm (FLASH) / 1.9 to 2.6 mm (TrueFISP). The intra-individual reproducibility ranged from 0.9 to 4.4% (FLASH) / 0.6 to 6.6% (TrueFISP), resulting in an average reproducibility of 2.8% (FLASH) / 3.8% (TrueFISP). The inter-individual variability of the mean patellar cartilage thickness was 10.7% (FLASH) / 11.3% (TrueFISP).

The maximum patellar cartilage thickness varied from 4.7 to 6.6 mm (FLASH) / 4.5 to 6.2 mm (TrueFISP). The intra-individual reproducibility ranged from 0.8 to 3.8% (FLASH) / 0.3 to 6.0 % (TrueFISP), resulting in an average reproducibility of 2.6% (FLASH) / 4.1% (TrueFISP). The inter-individual variability of the maximum patellar cartilage thickness was 12.2% (FLASH) / 12.0% (TrueFISP).

In all 3 data sets of the 6 volunteers, the patellar cartilage volume and thickness calculated from the TrueFISP images were smaller than in the FLASH images. However, differences were not significant ($p > 0.5$). Probably, the lower volume and thickness values resulting from the TrueFISP sequence might be attributable to the high signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the synovial fluid that tend to lead to an underestimation of cartilaginous tissue during segmentation (see arrows in figure 1). In healthy young adults, the intra-individual reproducibility of cartilage volume and thickness showed a tendency to lower values in the TrueFISP sequence, reflecting a more complex signal behaviour with a correspondingly (slightly) lower reliability of cartilage delineation. The inter-individual variabililty of cartilage volume and mean / maximum cartilage thickness was comparable for both sequence techniques.

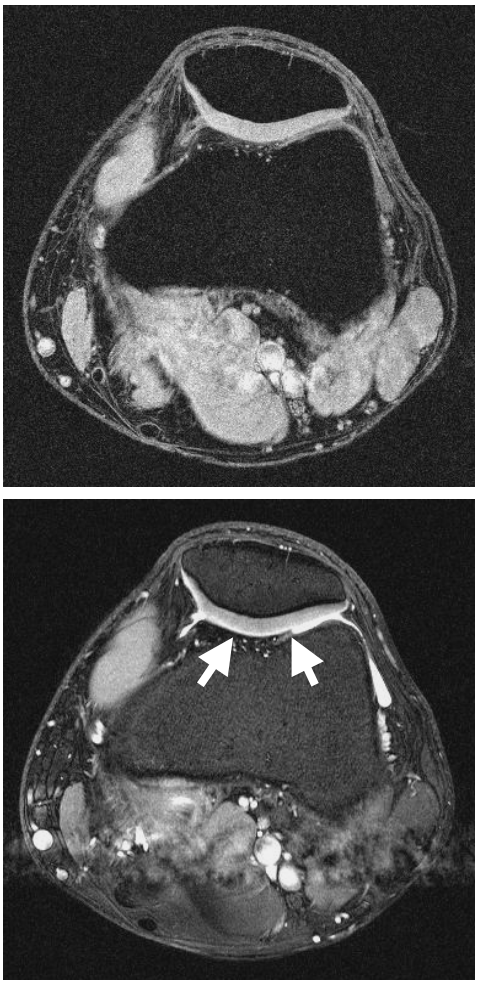

Figure 1: Appearance of cartilage as obtained from the FLASH (upper image) and the TrueFISP (lower image) sequence.

Conclusion:

In healthy volunteers, quantitative assessment of the patellar cartilage volume and thickness from the 3D-TrueFISP image data lead to smaller cartilage volume and thickness values as compared to the previously validated 3D-FLASH image data. Although recent studies have shown a significantly higher SNR-efficiency and cartilage-synovial fluid contrast for steady-state free precession techniques [7], that may improve cartilage segmentation especially in OA patients where cartilage-joint contrast is more difficult [8], in our subjects, the 3D-FLASH technique tended to provide a more reliable evaluation of quantitative cartilage parameters at 3.0T.

References:

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