PLANAR HIP CARTILAGE QUALITY MAPS – A NOVEL APPROACH TO 3D CARTILAGE ASSESSMENT BY COMBINING DGEMRIC WITH AUTOMATED SEGMENTATION

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Introduction

Delayed gadolinium enhanced MRI of cartilage (dGEMRIC) is a technique for molecular imaging of the proteoglycan level in cartilage using quantitative T1 measurements [1]. During recent years several methods have been developed for accurate T1 quantification in a full 3D volume [2]. However, very few applications utilize the possibilities associated with having such 3D data at hand. Instead, most evaluation of 3D dGEMRIC is still performed similar to how it was done with previous 2D methods.

In this work a method is presented for extracting the entire cartilage structure from the 3D T1 volume and present it as an intuitive planar map. In order to achieve this, modern automatic segmentation techniques are utilized, as manual segmentation of a 3D volume is far too time consuming for practical applications.

Methods

Images from ten hip patients, receiving dGEMRIC as part of their clinical care, were analyzed retrospectively. All scans were performed on a 1.5T scanner (Siemens Medical Systems). T1 quantification was performed 30 minutes after intravenous administration of a double dose Gd-DTPA2$^-$ using a 3D-VFA sequence (MapIt, Siemens Medical Systems) with isotropic 0.8 mm voxels (matrix 192x192x100, TR 15 ms, TE 4.75 ms. FA 5° and 28°) [3]. This was immediately followed by a TrueFISP sequence with isotropic 0.6 mm voxels (matrix 256x256x144, TR 12.57 ms, TE 5.48 ms). Both sequences were set to cover the same volume. Automated segmentation of a target volume was performed on the TrueFISP images using a label fusion method. First, a set of nine manually segmented training volumes was registered to the target volume, using a combination of rigid and non-rigid registration techniques [4]. The segmentation of the target volume was then estimated from the transformed training segmentations using the Local Map STAPLE algorithm [5]. The generated segmentation was then applied to the T1 volume, following rigid registration in order to compensate for any patient movement between the sequences. Cartilage outside the acetabular rim and in the area around fovea (Fig. 1) was automatically excluded. Finally, the segmented T1 values were averaged radially from the center of femur, followed by a Lambert Azimuthal Equal-Area cartographic projection algorithm to unfold the cartilage sphere to a planar T1 map (Figs. 2 and 3). The performance of the segmentation method was verified by a leave-one-out study comprising all ten subjects (Table 1), for which manual training segmentations of cartilage, femur and acetabulum were available.

Results

As is shown from the leave-one-out study, the performance of the automated segmentation method is excellent, measured both as average predictive value (PV) and as average Dice's coefficient (Table 1). A representative 3D segmentation of acetabulum and cartilage is shown in Fig. 1 with the corresponding planar T1 map for the same patient shown in Fig. 2. A planar map for an additional patient is shown in Fig. 3, in order to demonstrate that differences can be seen in the patterns of cartilage degeneration.

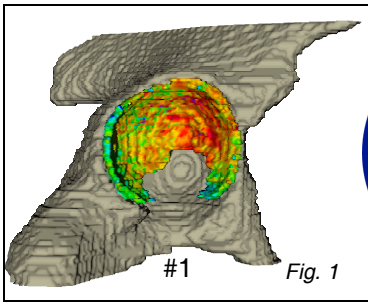


Fig. 1

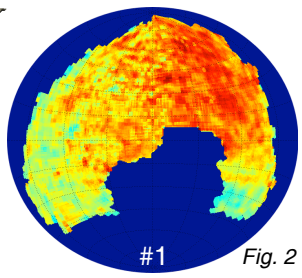


Fig. 2

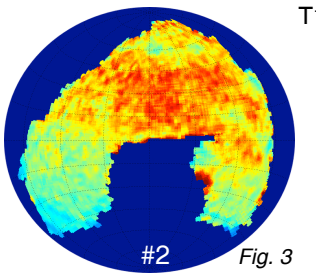
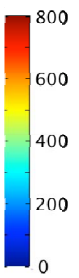


Fig. 3



Average segmentation results

	PV	Dice
Cartilage	0.93 (±0.03)	0.84 (±0.06)
Femur	0.98 (±0.01)	0.95 (±0.02)
Acetabulum	0.96 (±0.02)	0.91 (±0.02)

Table 1

Discussion and conclusions

In this work it has been shown that automated hip cartilage segmentation is both feasible and robust. It has further been shown that generating planar cartilage maps is a feasible method, which may have an important role in assessing cartilage quality. Related applications include selection for impingement surgery as well as selection for tissue engineering. Other applications include epidemiological studies where the patterns of degeneration may provide conclusions about the development of cartilage disease.

References

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