**CT arthrography of the knee to measure cartilage quality with low radiation exposure**

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<table>
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<th>Region of Interest</th>
<th>CTA 2.0 mSv</th>
<th>CTA 1.0 mSv</th>
<th>CTA 0.8 mSv</th>
<th>CTA 0.6 mSv</th>
<th>CTA 0.4 mSv</th>
<th>CTA 0.2 mSv</th>
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<tr>
<td>Pooled anatomical ROIs</td>
<td>R=0.81</td>
<td>R=0.75</td>
<td>R=0.74</td>
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Table 1. Correlation coefficients of mean attenuation from EPIC-\(\mu\)CT and CT arthrography obtained at different radiation doses. * \(p<0.0001\)

Introduction

Novel imaging techniques which measure cartilage quality in terms of the sulphated glycosaminoglycan (sGAG) content are valuable in osteoarthritis (OA) research. An example of such an imaging technique is in vivo \(\mu\)CT arthrography in small animals. Recently, we showed that CT arthrography (CTa) performed on a clinical CT system using human cadaveric knees is also capable of measuring cartilage quality in terms of the sGAG content.

Because of the relatively high radiation dose (~2 mSv per scan) of the CTa protocol compared to a standard CT of the knee (~0.2 mSv per scan), the radiation exposure must be decreased before CTa can be used in a clinical research setting. Therefore, the first aim of this study was to assess the effect of radiation dose reduction on the capability of CTa to measure overall cartilage quality. Second, we determined the capability of CTa to assess local cartilage quality within a single slice and the effect of radiation dose reduction on this assessment.

Methods

Seven human cadaveric knee joints were scanned on a second generation dual source multidetector spiral CT scanner (Definition Flash, Siemens, Germany) after an intra-articular injection of ioxaglate (30% dilution of Hexabrix 320, Mallinkrodt, USA). CT scans were acquired using six different radiation doses: 3140 (~2 mSv), 1570 (~1 mSv), 1256 (~0.8 mSv), 942 (~0.6 mSv), 628 (~0.4 mSv) and 314 (~0.2 mSv) mAs with a constant tube voltage of 80kV. Mean X-ray attenuation of all scans was calculated in seven large anatomical multisection regions of interest (ROIs) of cartilage: the weight-bearing (WB) and non weight-bearing areas of the medial and lateral femoral condyles, the WB medial and lateral tibial plateaus and the mid-portion of the patella.

Next, all knee joints were dissected and the femoral condyles, tibial plateaus and the patella were separated. After dissection, the same ROIs as in CTa were rescanned with equilibrium contrast-enhanced (EPIC)-\(\mu\)CT. EPIC-\(\mu\)CT served as reference standard because it accurately measures sGAG content and hence quality of cartilage. Mean attenuation in all \(\mu\)CT ROIs was calculated.

Finally, all \(\mu\)CT and CTa datasets per knee were registered to enable comparison of local cartilage quality on corresponding slices in all CTa scans. Areas of good and bad cartilage quality were defined on a mid sagittal slice through the tibiofemoral compartment and a mid-portion slice of the patella on CTa acquired at 3140 mAs using a visually selected attenuation threshold. These good and bad cartilage regions were compared with corresponding regions in the CTa scans with lower radiation dose. The mean attenuation in the good and bad cartilage regions was calculated for all CTa scans. Additionally, in a small ROI of intra-articular free ioxaglate, the standard deviation of the attenuation was calculated as a measure for noise in the CT images.

The correlation between mean X-ray attenuation values of the CTa and \(\mu\)CT in the anatomical ROIs was analyzed with linear regression to test if CTa acquired using lower radiation could still measure overall cartilage quality. To test if CTa could measure local good and bad cartilage quality, in the registered CTa scans the difference between attenuation in good and bad cartilage was compared using an unpaired t-test. Next, the contrast to noise ratio (CNR = mean_att_good_cart – mean_att_bad_cart / sd_att_contrast) was calculated in the condylar, patellar and plateau cartilage. Finally, the visual agreement for good and bad areas of cartilage was determined in all CTa scans.

Results

CTa attenuation values acquired using 2.0 mSv per scan correlated good with the reference EPIC-\(\mu\)CT values (R=0.81; R²=0.66; \(p<0.0001\)). The correlation for CTa attenuation values acquired using lower radiation dose decreased slightly, but remained good (R=0.75-0.74; R²=0.57-0.55; \(p<0.0001\)) (table 1).

In the registered single slices of all CTa scans there was a significant difference between the attenuation of the good and bad cartilage (p<0.0001). The CNR in the maximum dose CTa scans was high in all cartilage regions (2.97±0.95). Because of the decrease in radiation dose, the effect of radiation dose reduction on this assessment.

Discussion

The results of this study demonstrate that, even if CTa was obtained at lowered radiation doses which results in an increase in noise in the images, the correlation between EPIC-\(\mu\)CT and CTa only decreases little and CTa can still measure overall cartilage quality.

The results also demonstrate that CTa (at maximum dose and also at lower radiation doses) is capable of distinguishing good from bad cartilage quality within a single slice based on attenuation values. However, due to the decreased CNR it is impossible to visually discriminate between good and bad cartilage quality on a single slice if less than 0.6 mSv per scan was used. In addition, it is also important to take into account that only if the difference in attenuation between good and bad cartilage (image contrast) is big enough and the surface of the good and bad cartilage is large enough, CTa can distinguish between good and bad cartilage quality within a single slice.

In conclusion, CTa obtained at relative low radiation dose (minimum radiation 0.6 mSv per scan) is able to measure both overall and local articular cartilage quality throughout the whole human knee.

Significance

Low radiation CTa might be a fast and cheap alternative or supplement for MRI based techniques to quantitatively measure articular cartilage quality in clinical research.

References:

3Siebelt et al, Osteoarthritiis Cartilage accepted for publication, 2011.

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