**ACCURACY OF QMRI IN DETECTING FOCAL CARTILAGE DEFECTS AND GENERALIZED (DIFFUSE) OSTEOARTHRITIC CHANGES**

University of Frankfurt, Frankfurt, Germany

**Introduction:** Approximately one third of all adults suffer from symptoms of osteoarthritis (OA) [1] and focal cartilage defects can frequently be observed already in adolescents. Radiography represents the current gold standard in OA imaging, but cannot delineate the cartilage directly. Magnetic resonance imaging (MRI) has recently been shown to be accurate for quantifying cartilage thickness and volume in healthy joints if high resolution sequences and 3D image postprocessing techniques are applied [2, 3]. Only few studies with limited number of patients [4] have, however, examined whether MRI also permits one to quantify overall cartilage status in severe OA, and few studies have explored its capability to quantify focal cartilage defects [5].

The objective of this study was to analyze the validity of qMRI in the detection of a) general diffuse osteoarthritis, e.g., a larger patient cohort, and b) defined focal cartilage defects of the knee.

**Methods:**
Diffuse cartilage changes: For analyzing generalized cartilage loss in OA, high resolution MR images of the femoro-tibial and patellar cartilage were acquired in 21 patients, immediately prior to total knee arthroplasty (1.5T Magnetom Symphony, Siemens, Erlangen; Germany). A T1-weighted gradient echo sequence with water excitation was used at a spatial resolution of 0.31 mm and a slice thickness of 1.5 mm. The acquisition time was approx. 10 min for each compartment. After segmentation with a B-spline Snake algorithm, a) the original bone interface area (interface area before the onset of disease), b) the intact cartilage surface area, c) the percentage of bone interface area covered by cartilage, d) the cartilage thickness, and e) the cartilage volume were computed, using proprietary software. During surgery, the patella and the medial and lateral tibial plateau were resected. qMRI data were compared to direct image analysis of cartilage surface areas in retrieved specimens, to cartilage thickness of anatomical sections, and to cartilage volume of surgically removed tissue (Archimedes principle).

Focal cartilage defects: For analyzing focal cartilage defects, 25 other tibial and patellar joint surfaces were obtained during knee arthroplasty. In these, 74 cylindrical defects were artificially formed with a punch, with diameters of 3, 5, and 8 mm, respectively. Two approaches were used for creating the defects. In 16 specimen (51 defects) the cartilage cylinders were removed from the joint plate to obtain defects as observed, for instance in osteochondrosis disseicans (approach 1). In 14 specimen (23 defects), the cartilage cylinder was left in place and the surrounding cartilage tissue was removed mechanically (approach 2). The joint surface were then filled (in saline solution) with the same MRI solution, with and pulse sequence described above. For both approaches the cylinders were segmented semiautomatically. The person who performed the image postprocessing was blinded to the number of defects per surface, to position and size. The systematic and the random differences between the real known defect size and the size determined by postprocessing from the MR images were assessed and evaluated for statistical significance using a paired Student’s t-test.

**Results:**
Diffuse cartilage changes: The mean cartilage thickness displayed random differences of ±4.3 % in the patella to ±12.3 % in the medial tibia, with no systematic difference between qMRI and direct morphological analysis. The high correlation coefficients (r > 0.92, except for the cartilage thickness in the medial tibia) and relatively small standard errors confirmed a high linear relationship between values derived from qMRI and those measured postoperatively.

Pairwise differences in cartilage volume ranged from ±6.6 % (patella) to ±11.5 % (medial tibia), with a slight overestimation in the patella (+5.1 %, p < 0.05) and lateral tibia (+3.6 %; not significant), and a slight understimation in the medial tibia (-3.1 %; not significant).

The random differences for measures of surface areas (original bone interface area, cartilaginous surface area) were around ±8 % for the patella, medial, and lateral tibia, with the values from qMRI being significantly (p < 0.01) lower than those obtained by direct image analysis (Table 1). In contrast, the percentage of cartilaginous (or denuded) surface area displayed no systematic over- or underestimation between qMRI and image analysis, and random errors ranged from ±3.6 % (lateral tibia) to ±5.5 % (medial tibia).

Focal cartilage defects:
The artificially formed cartilage defects were all accurately detected by MRI analysis in terms of number and location. Regarding accurate measurement of the effect size with approach 1, the accuracy improved with the size of the defect. Random differences for the diameter were 1.3 ±0.3 mm (42%) in case of the 3 mm defects, 1.0 ±0.18 mm (20.3%) for the 5 mm defects and 0.1 ±0.08 mm (1.2%) for the 8 mm defects. While there was a significant overestimation for defect size for 3 mm (+42%; p < 0.05) and 5 mm defects (+20%; p < 0.05), no systematic error was observed for 8 mm defects. With approach 2, the degree of accuracy was slightly higher compared with approach 1. Random differences were 0.6 ±0.4 mm (18%) for 5 mm defects and 0.09 ±0.1 mm (3%) for 8 mm defects. There was no significant over- or underestimation with this approach in either the 5 mm or 8 mm defects.

**Conclusions:** These findings strongly support the notion that qMRI now permits to quantitatively and directly measure cartilage status in OA. The results show that in generalized (diffuse) OA changes, qMRI now permits one to differentiate a reduction in cartilage thickness from that of a reduction in the percentage of cartilaginous surface area. It is important to note that these two processes cannot be differentiated when only the cartilage volume is determined. Moreover, the current results demonstrate that qMRI allows one to accurately quantify focal cartilage defects. No important differences were observed between approach 1 and 2 for forming the defects. We thus recommend that technique 1 should be used in future studies, since this defect form is similar to that observed in patients. The results show that, the accuracy depends on the size of the defect: While in 3 mm defects the overestimation amounted to 42 % (1.3 mm), the difference in 8 mm was only 1.2 % (0.1 mm). The overestimation of smaller defects is likely due to the limited in-plane resolution of 0.31 mm and partial volume effects. As Link et al. [5] have shown that there exists a close relationship between the resolution and the detectability of focal lesions. Although higher in plane resolutions are technically feasible, these inevitable lead to a substantial increase in imaging time, which limits the clinical practicability of the protocols. Since most of the defects in osteochondrosis disseicans (and OA) are generally larger than 1 cm in diameter, the technique presented is, however, sufficient for detecting and quantifying these lesions.

In summary, qMRI is shown to provide high accurate information on cartilage status in both generalized (diffuse) OA and in focal cartilage damage. This may provide important advantages in diagnosing general and focal OA, understanding OA progression, and testing the responsiveness to new medical and surgical therapies.