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3D THICKNESS MAPS DERIVED FROM AUTOMATED SEGMENTATION OF KNEE ARTICULAR CARTILAGE AT 1.5 T: A FEASIBILITY STUDY USING 3D FS DESS, 3D PD FS FSE, AND 2D PD FS FSE

J.M. Farber, J. Tamez-Pena, S. Totterman, K. Baum, E. Schreyer, E. Brandser. Qmetrics, Cincinnati, OH, USA; QmetricsTec de Monterry, Monterry, Mexico; Qmetrics, Rochester, NY, USA; Qmetrics, Rochester, NY, USA

Purpose: To evaluate the feasibility of using 3D FS DESS, 3D PD FS FSE and 2D PD FS FSE at 1.5 T to generate 3D articular cartilage (AC) thickness maps with an atlas based, voxel by voxel automated segmentation platform.

Methods: High in-plane resolution, thin slice sequencing was performed at 1.5 T. 3D FS DESS sequences were obtained on Siemens equipment (Avanto, Germany). 3D PD FS FSE and 2D PD FS FSE sequences were obtained on GE equipment (450W, USA). All sequences had in-plane resolution of 384 x 384. The slice thickness of the 3D FS DESS and 3D PD FS FSE sequences ranged from 0.7 to 2.0 mm. The slice thickness of the 2D PD FS FSE sequence was 2.0 mm. All sequences were optimized to enhance AC segmentation, including the selection of a TE appropriate to AC visualization, that is, a TE of 16–18. For the atlases, 3D FS DESS data from the Osteoarthritis Initiative (OAI, NIH) were used. The atlases consisted of six data sets, and the segmentation platform (Qmetrics, USA) has been validated (1). For all scans, an eight channel dedicated knee coil was used. Twenty segmented data sets of each sequence were evaluated by two experienced MSK radiologists – each with over 20 years of experience – for accuracy of AC segmentation, including inclusion of defects and exclusion of non-AC tissues. For this feasibility study, subject exclusion criteria included prior surgery or a K-L score > 2. When required, editing was performed on the segmented images using the automated platform’s editing tools, before the 3D thickness maps were generated.

Results: The three sequences tested at 1.5 T all segmented; with some data sets, minor editing was required for proper segmentation before generating the 3D thickness maps. When required, the editing process was performed by the experienced MSK radiologist, and the editing took 10–15 minutes or less. Unexpectedly, although the atlases were created from OAI 3D FS DESS data sets, PD based sequences, 3D and 2D, segmented robustly (Fig. 1). 3D thickness maps were created from each sequence acquisition seamlessly by the automated platform.

Conclusion: With proper sequencing and supervision, atlas based, voxel by voxel segmentation and the subsequent generation of 3D thickness maps is feasible at 1.5T with a variety of sequences. This result creates the possibility of AC segmentation with sundry sequences, giving radiologists flexibility in sequence selection. The creation of sequence specific atlases presumably will improve segmentation results, and result in concomitant less editing. Further work will address this presumption, with surgical correlation.


Fig. 1. Sagittal images (a, b and c) of the knee with - from left to right - 3D FS DESS, 3D PD FS FSE and 2D PD FS FSE. All data sets were obtained at 1.5T, and all data sets were amenable to automated segmentation. The far right image, d, is representative of the thickness maps derived from the voxel by voxel segmentation.
this study we sought to identify the cellular and morphological changes that associate with increased 99mTc-DPD uptake in ankle joint osteoarthritis (OA).

**Methods:** Six patients (mean age 63, range 52–73) scheduled for total ankle replacement due to OA received preoperative 99mTc-DPD SPECT/CT scanning. Osseous uptake was scanned four hours after intravenous administration of radiotracer (740 MBq). The American Orthopedic Foot and Ankle Score (AOFAS) and visual analog scale (VAS) were used for clinical evaluation of function and pain. Intra-operative distal tibial and talar resections were harvested and immediately fixed. Using SPECT/CT scans for guidance, standardized tissue samples (5 × 5 mm) were taken from areas with and without 99mTc-DPD (assessed by SPECT) and subchondral bone sclerosis (assessed by CT), respectively. Sagittal histological sections were stained with haematoxylin and eosin (HE), Safranin-O and van Gieson’s stain for evaluation of tissue morphology. Osteoclast activity was visualized using staining for tartrate-resistant acid phosphatase (TRAP).

**Results:** Preoperative AOFAS score and VAS were 40 ± 15 (range 20–56) and 7.5 ± 0.84 (range 7–9), respectively. The spatial distribution of SPECT/CT-positive lesions was heterogeneous, with hotspots located in four tibial and two talar resections at an average depth of 1.04 ± 0.60 mm beneath the subchondral bone plate. Radiotracer uptake was exclusively found in areas displaying subchondral bone sclerosis, while tracer-negative areas were both nonsclerotic and sclerotic. Severe cartilage degeneration was apparent (median Mankin score 7.5, range 2.0–10), but failed to significantly correlate with increased radiotracer uptake (r = 0.549, p = 0.2). HE staining revealed masked infiltration of subchondral marrow spaces by fibrovascular tissue. Large numbers of bone-lining osteoblasts were detected in areas with increased 99mTc-DPD uptake (Fig. a). Van Gieson’s staining showed that osteoblasts were surrounded by randomly organized collagen fibers, which indicates woven bone formation as a result of rapid osteoid production (Fig. b). Osteoblast presence was significantly correlated with radiotracer uptake (r = 0.60), collagen deposition (r = 0.83) and degree of cartilage degeneration (r = 0.85). De novo bone tissue was devoid of osteoclast activity (Fig. c), which suggests arises from pure intramembranous bone formation rather than remodeling from pre-existing subchondral bone. **Conclusions:** Osteoclast activity of bone-seeking 99mTc-DPD tracer in human ankle OA is due to intramembranous bone formation. Lack of osteoclast activity might impair the therapeutic efficacy of anti-resorptive drugs in this joint. SPECT/CT imaging is crucial for diagnosis and planning surgical interventions in ankle OA.

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**493 MAGNETIC RESONANCE IMAGING SCORING OF AN EXPERIMENTAL MODEL OF OSTEOARTHRITIS IN THE EQUINE CARPUS**

A.D. Smith †, A. Morton †, P. Colahan †, M. Winter †, S. Ghivizzani †, N. Brown †, J. Hernandez †, † Univ. of Florida Coll. of Vet. Med., Gainesville, FL, USA; ‡ Univ. of Florida Coll. of Med., Gainesville, FL, USA

**Purpose:** The equine carpal osteochondral fragment model has been used translationally for osteoarthritis (OA) research in humans. Macroscopic and histological evaluations of the pathologic changes identified using terminal studies have previously been reported, however, little is known about the progression of pathological changes that occur following creation of the osteochondral fragment. Magnetic resonance imaging (MRI) is non-invasive and allows three-dimensional imaging of all joint components. Semi-quantitative MRI scoring systems have been used to characterize joint disease and reliably predict progression of OA in other species. The purpose of this study was to document the progression and severity of pathological changes in an experimental equine carpal OA model using MRI.

**Methods:** Ten healthy, treadmill-conditioned, adult horses free of lameness and radiographic signs of carpal disease were used in the study. On day 0, an osteochondral fragment was created in one middle carpal joint (OA) and the contralateral joint (control) was sham-operated. On day 14, horses resumed exercise on a high-speed treadmill until the completion of the study (day 70). MRI examinations were performed in a 1.5T clinical unit (Toshiba Titan, Japan) under general anesthesia using standard imaging sequences including sagittal and axial proton density (PD), sagittal and dorsal PD with fat suppression, dorsal T2, axial T2 short tau inversion recovery (STIR), and dorsal spoiled gradient echo with fat suppression. A semi-quantitative whole organ scoring system, adapted for use in the equine middle carpal joint, was used to score each joint on days 0 (prior to induction of OA), 14, and 70 by three blinded investigators (a large animal surgeon, a veterinary radiologist, and a large animal surgery resident). The cuboidal bones of the middle carpal joint were divided into 9 articular sub-regions (2nd and 3rd facet of the radial carpal bone, 3rd and 4th facet of the intermediate carpal bone, ulnar carpal bone, 2nd carpal bone, radial and intermediate facet of the 3rd carpal bone, and 4th carpal bone). Each sub-region was assessed for presence of cartilaginous defects (0–3), distribution (0–3) and intensity (0–3) of bone marrow edema-like lesions (BML), subchondral bone irregularity (0–4), subchondral bone sclerosis (0–3), and osteophyte formation (0–3). Abnormalities needed to originate from the middle carpal joint to be scored. Soft tissue structures associated with the middle carpal joint including the lateral and medial collateral ligaments, dorsal medial intercarpal ligament, and lateral and medial palmar intercarpal ligaments, were assessed separately and graded as normal (0) or abnormal (1). Osteochondral fragments were scored based on number (0–3) and size (0–3). Lastly, effusion and synovitis were scored and graded on a scale from 0–3 each. A maximum cumulative score of 188 was possible. If there were a discrepancy between the investigators about assigned scores, two MRI images, a final score was assigned by consensus opinion. Continuous data were expressed as mean ± standard deviation. Each score was compared between and within groups at the different time points using the non-parametric Wilcoxon sign rank test with significance set at P < 0.05.

**Results:** On day 0, no differences were noted between OA and control joints. When comparing OA joints on day 0 and day 14, there were significant increases in both distribution and intensity of BML in both the 2nd and 3rd facet of the radial carpal bone, osteochondral fragment number and size, effusion, and total scores. Osteophyte formation scores of the 2nd facet of the radial carpal bone were significantly increased in OA joints on day 70 when compared to day 0. Osteophyte formation, cartilage abnormality, and subchondral bone irregularity scores of the 3rd facet of the radial carpal bone were significantly increased on day 70 compared to days 0 and 14 in OA carpi. Third carpal bone cartilage abnormalities scores and synovitis scores were also significantly increased on day 70 compared to days 0 and 14 in OA carpi. BML distribution and intensity scores in both the 2nd and 3rd facet of the radial carpal bone and osteochondral fragment size were significantly decreased on day 70 when compared to day 14 in OA carpi.

**Conclusions:** A semi-quantitative MRI scoring system identified acute and chronic pathological changes in an established model of OA in the equine carpus. These results show that MRI could play a role in helping define the onset and progression of post-traumatic OA following acute joint injury. MRI also shows promise for potential use as a biomarker in future equine models of OA.

**494 MICRO-STRUCTURAL BONE VARIATIONS ASSESSED BY MICRO-COMPUTED TOMOGRAPHY OF THE MEDIAL TIBIAL PLATEAU IN HUMANS WITH AND WITHOUT OSTEOARTHRITIS AT DIFFERENT LOCATIONS**

S. Touraine, L. Lauoissert, V. Bousson, J-D. Laredo, C. Chappard. CNRS-CNRS-UNIR 7052, Laboratoire B20A, Université Paris-Diderot, Sorbonne Paris Cité, Paris, France

**Purpose:** The aim of this study is to determine the influence of osteoarthritis on the subchondral bone microarchitecture in terms of depth in different locations of the medial tibial plateau.

**Methods:** Twenty four non-embalmed and unpaired (left) human knees were obtained from a population of 14 (58.3%) women and 10 (41.7%) men with a mean age of 85.4 years ± 8.57 and 82.7 years ± 11.54 respectively. The specimens were radiographed and categorized in knees without or with radiographic osteoarthritis in the medial femorotibial compartment (OA+ or OA− respectively) using the Kellgren-Lawrence grading scale (OA− for grade ≥ 2). After dissection, 3 calibrated vertical samples of each medial tibial plateau (7 mm in diameter,