

Functional PET-MRI in Symptomatic Cam FAI Examining the Crosstalk Between Bone and Cartilage

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INTRODUCTION: Cam morphology of the hip may predispose to Femoroacetabular Impingement (FAI) and osteoarthritis (OA). Understanding the biological and functional changes in FAI may provide insight into the early stages of OA and allow for the development of a predictive biomarker. Magnetic Resonance Imaging (MRI) T1ρ mapping gives information on proteoglycan content in hyaline cartilage, while Positron Emission Tomography (PET) allows for functional imaging of bone turnover. In this study, simultaneous PET-MRI was performed to analyze bone and cartilage in hips with symptomatic cam FAI and healthy controls.

METHODS: 3T PET-MRI was used to study two groups: symptomatic cam FAI scheduled for surgical intervention (n=24, mean age: 31.7±7.9 years), and healthy controls (n=18, mean age: 29.8±7.5 years). MRI T1ρ maps were acquired as markers for hip cartilage proteoglycan content, 18F-NaF-PET Standard Uptake Values (SUVs) for bone turnover in the acetabulum and femur. The cartilage was divided into 6 regions: anterior lateral, anterior intermediate, anterior medial, posterior lateral, posterior intermediate, and posterior medial. The acetabulum was divided into 6 regions anterior to posterior (region 1 being the most anterior and region 6 being the most posterior), with each region spanning the entire medial-to-lateral area. The femoral head neck junction (FHNJ) regions were divided into four subregions (superior anterior, superior posterior, inferior anterior, and inferior posterior). Patient Reported Outcome Measures (PROMs) were collected for the symptomatic group using the Hip Disability and Osteoarthritis Outcome Score (HOOS), EQ-5D-5L, and the International Hip Outcome Tool (iHOT-33). Kruskal-Wallis, pairwise Wilcoxon tests, and Spearman correlations (r) were used to compare measures between groups, the significance level was p < 0.05.

RESULTS: For the symptomatic group, significant positive correlations (higher T1ρ values with higher bone activity) were observed between T1ρ anterior medial and full anterior cartilage with the maximum SUV in several regions of acetabulum (1, 3, 5, 6, and full anterior) and between T1ρ in the anterior medial cartilage with maximum SUV in FHNJ regions, although the correlations were not strong (-0.6<r<-0.4). A significant, negative correlation was observed between T1ρ in the posterior lateral region of cartilage with the maximum SUV in FHNJ 2, although it was not a strong correlation (r=-0.42). For the healthy control group, significant negative correlations (-0.6<r<-0.57) were observed between T1ρ in the posterior lateral region of cartilage with three regions of maximum SUV in the acetabulum (2, 3, and full anterior). A strong (r < -0.7), significant, negative correlation was observed between SUV in two regions of the femoral head-neck junction with the EQ-5D-5L. Good (r < -0.6), significant, negative correlations of the SUV in full FHNJ region was found with iHOT-33 parameters related to symptoms and the HOOS function parameter. A significant negative correlation was found between the HOOS pain parameter with SUV in acetabulum (r = -0.44), and the HOOS pain parameter with T1ρ in the anterior cartilage (r = -0.50). Good, significant, negative correlations were also observed between T1ρ in the anterior medial region of cartilage with iHOT-33 parameters (-0.69<r<-0.60). T1ρ, analyzed as a bilayer (femur and acetabulum), was significantly increased in posterior regions of cartilage for the symptomatic group compared to the control group. A trend of increased SUV in the femur for the symptomatic group compared to healthy controls was observed, although not significant.

DISCUSSION: The positive correlations between T1ρ and SUV in the symptomatic group indicate an association of spatially matched cartilage degeneration with ongoing active bone remodeling. The observed positive correlations of increased T1ρ in the cartilage anterior regions with increased bone activity in several regions of the acetabulum as well as the whole anterior part of the acetabulum suggest an ongoing process of the impact of the cam deformity on both, the bone and cartilage. The positive correlation between T1ρ in the lateral region with SUV in regions of the femoral head neck also indicates an active remodelling in the cam deformity with cartilage degeneration correlating to the area of impingement. Interestingly, the cartilage regions posteriorly showed a fair negative correlation with the bone activity in the femoral head-neck junction, suggesting a decreased impact or completed process of remodelling with cartilage degeneration. In the healthy group a negative correlation was found between T1ρ posterior lateral and SUV in the anterior acetabulum. As the SUV in this region is not significant different between the groups this correlation might be related to the overall better cartilage health in the posterior region compared to the symptomatic group. Negative correlations between SUV and PROM parameters suggest increased bone remodeling is associated with increased pain and worsening quality of life factors. Negative correlations between T1ρ and PROM parameters indicates increased pain and worsening quality of life factors during early stages of cartilage degeneration. Increased T1ρ in the symptomatic group indicates early stages of cartilage degeneration in FAI patients. Increased SUV in the symptomatic group indicates active bone remodeling occurring in symptomatic presentations of FAI. T1ρ results indicate early stages of cartilage degeneration, while SUV results suggest concomitant increased bone remodeling in the symptomatic group compared to healthy controls. The positive correlation between T1ρ and SUV suggest an association of cartilage degeneration and bone remodeling in the symptomatic group. Both measures are associated with worsening pain and quality of life, as demonstrated through the PROMs results.

SIGNIFICANCE/CLINICAL RELEVANCE: PET-MRI has allowed for the simultaneous analysis of bone and cartilage status in hips and may be a useful approach to FAI and osteoarthritis diagnosis and prognosis.

IMAGES AND TABLES: Example images showing T1ρ maps (left), and SUV maps (right) obtained of a symptomatic FAI patient (top) and a healthy control (bottom). Regions of increased T1ρ and SUV can be seen in the symptomatic FAI patient images, when compared to the healthy control.

