

EXTRACTING VOXEL-BASED CARTILAGE RELAXOMETRY FEATURES IN PERSONS WITH HIP OSTEOARTHRITIS USING PRINCIPAL COMPONENT ANALYSIS

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PURPOSE: Cartilage relaxation time mapping from magnetic resonance (MR) imaging reveals the composition and integrity of the cartilage in vivo and non-invasively. Traditional analysis is typically limited to analyzing average $T_{1\rho}$ and T_2 values in specific compartments. More recently, voxel-based relaxometry (VBR) for quantifying $T_{1\rho}$ and T_2 values has been introduced [1], providing the advantage of performing voxel-based statistical parametric mapping such as principal component analysis (PCA) [2]. In this study, we proposed to incorporate VBR and PCA to extract distinctive cartilage relaxation features in persons with hip osteoarthritis (OA).

SUBJECTS: Thirty-three subjects with radiographic hip OA (sex, 20 males; age, 50.2 ± 13.3 years; BMI, 23.5 ± 3.0 kg/m²) and 55 control subjects (sex, 28 males; age, 41.3 ± 12.0 years; BMI, 24.0 ± 3.1 kg/m²) from a longitudinal hip OA cohort participated.

METHODS AND MATERIALS: Pelvic X-ray was performed to determine the radiographic signs of hip OA using the Kellgren-Lawrence [KL] grade (OA: KL grades of 2 or 3; controls: KL grades of 0 or 1). MR assessment included a 3D SPGR sequence for semi-automatic cartilage segmentation and a combined $T_{1\rho}/T_2$ sequence for cartilage relaxation assessment. For the VBR analysis, briefly, all subject data were registered and mapped to an atlas consisting of the femur and acetabulum [1]. $T_{1\rho}$ and T_2 values at each voxel were converted in Z-score by considering the average and standard deviation of 7 “supercontrols” (defined as no morphological cartilage lesion over 3 years). Finally, PCA was used to extract principal components (PCs) in which each PC describes a specific relaxation feature. The first 5 PCs from each $T_{1\rho}$ and T_2 were considered in our analysis. Logistic regression was then used to identify possible predictors that were able to distinguish subjects with and without OA, with the covariates of sex, age, and BMI.

RESULTS: Two PCs from $T_{1\rho}$ and 1 PC from T_2 mapping were observed as significant predictors of group classification. In $T_{1\rho}$ mapping, modeling of PC2 ($p=0.012$) demonstrated that OA subjects exhibited a feature of higher $T_{1\rho}$ values in the acetabulum compared to femur cartilage, suggesting a cartilage site effect (Figure 1). Modeling of PC4 ($p=0.001$) demonstrated that OA subjects exhibited higher $T_{1\rho}$ values in the deep cartilage layer compared to the superficial layer, emphasizing a laminar effect (Figure 2). Lastly, in T_2 mapping, modeling of PC5 ($p<0.001$) demonstrated that OA subjects exhibited higher T_2 values in the posterior hip region, suggesting a regional effect (Figure 3).

CONCLUSIONS: Using VBR methods coupled with PCA, we were able to identify distinctive cartilage relaxation features that distinguish persons with or without radiographic hip OA. Persons with hip OA exhibit characteristics of higher $T_{1\rho}$ values in the acetabulum cartilage, higher $T_{1\rho}$ values in the deep cartilage layer, and higher T_2 values in the posterior hip region when compared to controls.

SIGNIFICANCE: Our analysis provides a better feature extraction of cartilage relaxation times beyond the well-known global increased $T_{1\rho}$ and T_2 values in persons with OA. This could be potentially useful in identifying the imaging biomarkers for the early stratification of persons at risk of developing post-traumatic OA.

ABSTRACTS

To incorporate voxel-based relaxometry and principal component analysis to extract distinctive cartilage relaxation features. Persons with hip OA exhibit characteristics of higher $T_{1\rho}$ values in the acetabulum cartilage, higher $T_{1\rho}$ values in the deep cartilage layer, and higher T_2 values in the posterior hip region when compared to controls.

REFERENCES

1. Padoia V, et al. *J Magn Reson Imaging*, 2017.
2. Padoia V, et al. *Quant Imaging Med Surg*, 2016

FIGURES

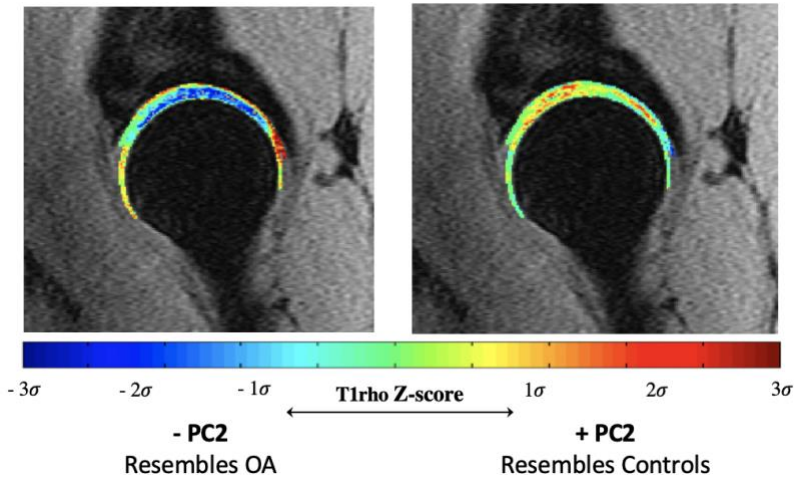


Figure 1. Modeling of T $_{1\rho}$ -PC2 demonstrated cartilage site effect: OA subjects (left) exhibited higher T $_{1\rho}$ values in the acetabulum as to femur cartilage.

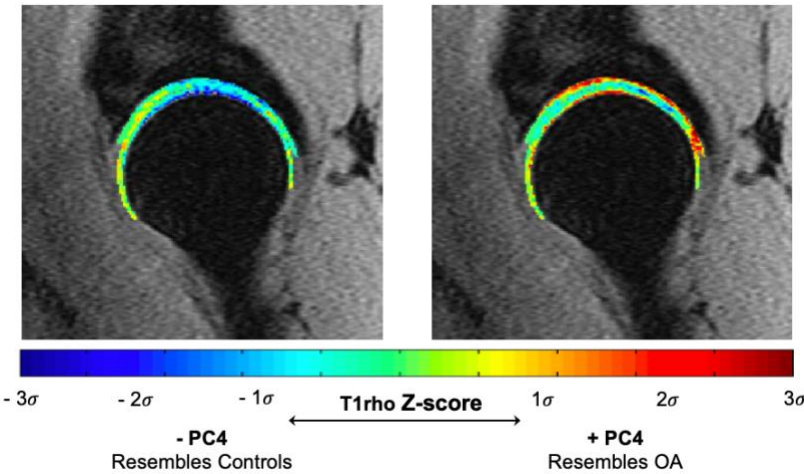


Figure 2. Modeling of T $_{1\rho}$ -PC4 demonstrated laminar effect: OA subjects (right) exhibited higher T $_{1\rho}$ values in the deep cartilage layer as to superficial layer

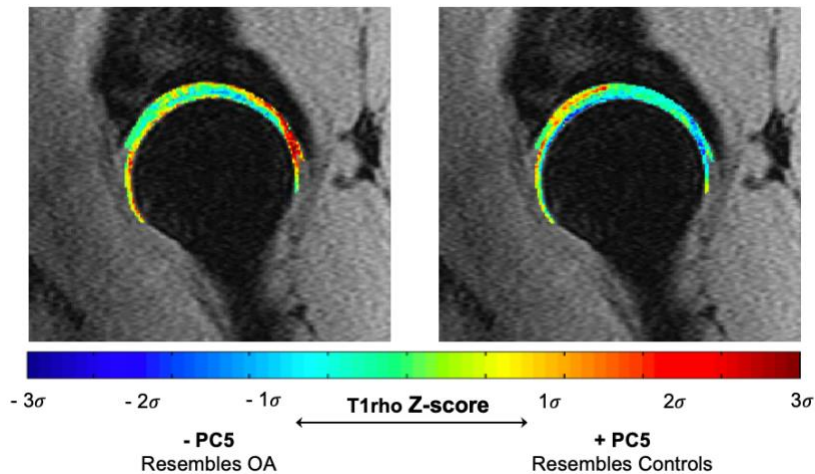


Figure 3. Modeling of T $_2$ -PC5 demonstrated regional effect: OA subjects (left) exhibited higher T $_2$ values in the posterior hip region.