MRI signal texture parameters within human intervertebral discs as biomarkers of spine pathologies and severities

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TARGET AUDIENCE: Orthopaedists will benefit from the evaluation of the intervertebral disc degeneration with scoliosis and spondylolisthesis through texture parameters on clinical MRI images. Physicians will value the statistical approach used to quantify the distribution of the MRI signal.

PURPOSE: In both scoliosis and spondylolisthesis, the progression of the spine deformation leads to the degeneration of intervertebral discs (IVD) characterized by a change in its structure and biochemical composition. Researchers confirmed that MR images of the human brain contain tissue-specific texture parameters which can differentiate healthy from pathological tissues [1]. The long term goal of this study is to help predict pathology progression using a sensitive and noninvasive technique. We assume that the features of tissue-specific texture can discriminate the pathologies and their severity in intervertebral discs. Our aim is to find a combination of biomarkers that best describe spinal deformities and their severities.

METHODS:
The MR images of a cohort of seventy-nine patients (32 with scoliosis, 32 with spondylolisthesis and 15 with herniated IVD), distributed in five different groups according to the pathology and its severity, were analysed after the approval of the ethic committee of our institutions. Subjects were between 8 and 20 years olds. There were sixteen patients in the low severity scoliosis group (Cobb angle: 13 to 47), sixteen in the high severity scoliosis group (Cobb angle: 48 to 89), sixteen in the low severity spondylolisthesis group (Meyerding grade: I and II), sixteen in the high severity spondylolisthesis group (Meyerding grade: III toV), and fifteen in the control group (non-degenerated discs according to the Pfirrmann classification analysed on patients with herniation). For each patient, six to twelve sagittal T2-weighted MRI slices were analysed. The segmentation of the disc was completed using the Snake algorithm [2]. From the initial grey level MR image, four images of texture were computed using the Gray-Level Co-occurrence Matrix. Eighteen statistical texture parameters were extracted from the intensity histograms of the grey level image and four texture images for a total of 90 features per disc. In order to minimize classification errors, an ANOVA was used to select a combination of sensitive features to the Cobb angle for scoliosis and to the Meyerding grade for spondylolistheis. A principal component analysis (PCA) was performed to reduce the number of significant variables and agglomerative hierarchical clustering (AHC) was used to separate observations with similar performances.

RESULTS: When considering the mean disc texture parameters of the 79 patients from the 5 groups, the PCA showed a cumulative variability of 88% for the five first principal components. The AHC was able to isolate each pathology from the control group, but not the severity of scoliosis or spondylolisthesis (Figure 1). However, when considering the mean disc texture parameters of the 32 spondylolisthesis patients only, the AHC proposed three clusters, one with low severity cases (Meyerding grade 1-2-3), one with high severity cases (Meyerding grade 4-5) and one with moderate severity cases (Meyerding grade 2-3-4). When considering the mean disc texture parameters of the 32 scoliotic patients only, the AHC analysis produced three clusters, one with mainly low severity cases (Cobb angle <47°), one with mainly high severity cases (Cobb angle >50°) and one with both low and high severities.

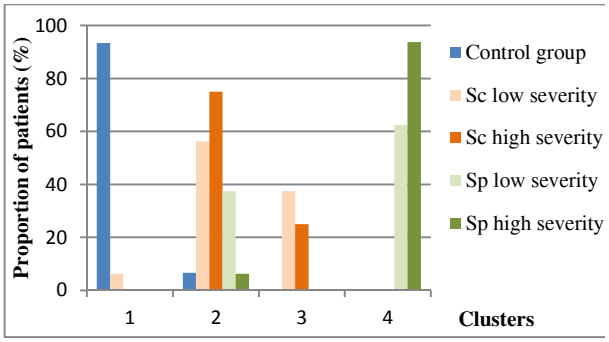

Figure 1: Clusters obtained from the texture parameters of the 79 patients, Sc for scoliosis and Sp for spondylolisthesis.

DISCUSSION: Texture analysis was performed for the first time on MR images of intervertebral discs using a statistical method. The results validated our hypothesis: the calculated tissue-specific texture features can effectively discriminate the pathologies and some of their severities. The intervertebral disc degeneration presents different structure patterns for scoliosis than for spondylolisthesis. These structure patterns were characterized by the texture parameters we proposed in this study. The more severe is the spine deformation, the more degenerated is the intervertebral disc, which supports our long term hypothesis that predictive factors of spine deformities progression could be extracted from the MRI signal distribution within the IVD. However, longitudinal studies are necessary to validate this hypothesis. The limits of this study are the semi-automatic segmentation which intra-observator reproducibility was proven [2], the low resolution of the MRI images that could be increased using post-processing algorithms [3] and finally the repartition of patients in the five groups that could be improved by the inclusion of more patients.

CONCLUSION: While this study is more on the descriptive level, it has the advantage of supporting the interesting possibility of developing robust non-invasive predictive methods for the diagnosis of the severities of spine pathologies. Once the influencing parameters as well as the relationships between them are clearly defined and validated, decision support tools for clinical use can be developed.

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