Distribution of MR signal intensity within the intervertebral disc: modifications occurring with adolescent spondylolisthesis and idiopathic scoliosis

D. PÉRIÉ[1,2], M. RIOPEL-METHOT[1,2], A. COURVILLE-LEBOUYONNEC[1,2], AND D. CURNIER[3]
[1]MECHANICAL ENGINEERING, ECOLE POLYTECHNIQUE, MONTREAL, QUEBEC, CANADA, [2]RESEARCH CENTER, CHU SAINTE JUSTINE, MONTREAL, QUEBEC, CANADA,
[3]KINESIOLOGY, UNIVERSITÉ DE MONTRÉAL, MONTREAL, QUEBEC, CANADA

INTRODUCTION

The nucleus pulposus is a viscous gel approximately centrally located within the intervertebral disc. Disc degeneration is characterized by a loss of cellularity, degradation of the extracellular matrix, and, as a result, morphological changes and biomechanical alterations. Early MRI work on intervertebral discs in patients with back pain consisted in the detection of degenerative disc abnormalities. Changes in the intervertebral disc height, area or volume have been widely quantified from MR images to highlight the effect of daily activities or various loading of the spine. The displacements of the nucleus zone were also measured from MR images, highlighting significant correlations with the flexion-extension movements of the spine, or with the intervertebral disc wedging in scoliosis. We hypothesize that the distribution of the MR signal intensity within the nucleus zone is dependent on the disease and the level of the disease. Thus, the aim of this study was to propose new parameters characterising the distribution of the MR signal intensity within the nucleus zone of the lumbar intervertebral disc, and to quantify them on patients with spondylolisthesis or idiopathic scoliosis.

METHOD

Fourteen adolescent patients with spondylolisthesis and fifteen adolescent patients with idiopathic scoliosis have been included in this study. They underwent an MRI acquisition composed of T2-weighted sagittal slices of the lumbar spine (Spin-Echo, TR/TE=3200/124). Three levels of spondylolisthesis were defined, level 1 for grade I and II, level 2 for grade III and IV, and level 3 for grade V on the Meyerding's classification. Three levels of scoliosis were also defined, level 1 for Cobb angles less than 20°, level 2 for Cobb angles between 21 and 40° and level 3 for Cobb angles superior to 41°. Each lumbar intervertebral disc was analysed using its central MR slice (Figure 1). The high intensity zone of the nucleus pulposus was semi-automatically detected. The geometrical center and the height of the nucleus were quantified. A center weighted by the signal intensity within the nucleus was determined, and its distance to the geometrical center on the longitudinal axis of the disc was called DX. The sum of the signal intensity on the perpendicular axis to the longitudinal axis of the disc was plotted for each position of the longitudinal axis allowing defining the maximum sum SM and its position PSM (Figure 2). Two-way ANOVA was used to analyse the data. The disease (scoliosis vs spondylolisthesis) was the first factor, and the level of disease (1 to 3) was the second factor. The reproducibility of the method was tested by two observators who realised the analysis three times on a same patient.

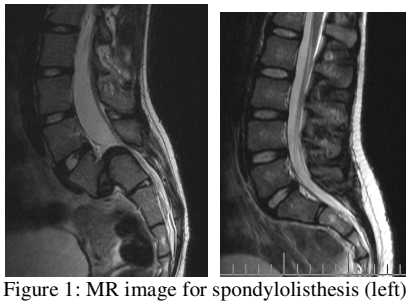

Figure 1: MR image for spondylolisthesis (left) and scoliosis (right)

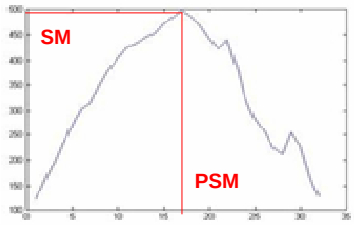

Figure 2: Sum of signal intensities plotted for each point of the longitudinal axis

RESULTS

The reproducibility analysis showed standard deviations inferior to 0.02mm for DX, H or PSM, and to 0.6 for SM. The L5/S1 disc in spondylolisthesis was largely degenerated from grade II to V, with low signal intensity and absence of high intensity zone, preventing its analysis. SM was higher and PSM was more shifted for scoliosis than for spondylolisthesis. This shift decreased with increasing the disease level. DX decreased with increasing the scoliosis level whereas it increased with increasing the spondylolisthesis level. The ANOVA showed that the differences observed on DX were not attributed to the disease ($p=0.62$) nor its level ($p=0.94$), the differences observed on SM were attributed to the disease ($p<0.001$) but not to its level ($p=0.21$), the differences observed on PSM were attributed to both the disease ($p<0.001$) and its level ($p=0.003$), and the differences observed on H were attributed to the level of the disease ($p=0.05$) but not to the disease ($p=0.42$).

DISCUSSION

A retrospective study had been performed on MR images of patients suffering from spondylolisthesis and scoliosis, and revealed modifications in the distribution of the MR signal intensity within the nucleus zone, which were attributed to the disease and its level. DX is not sensible to the changes due to the disease because the small modifications that could appear within the distribution of the signal intensities are averaged. Moreover, for scoliosis, the analysis was performed in the sagittal plane, which is not the plane of maximal deformities, and for spondylolisthesis, only the adjacent discs were analysed. However, PSM is a promising parameter sensible to the changes due to the disease and its level. Future developments will consist of a 3D analysis with the definition of new 3D parameters. The use of specific filters to analyse the images will be optimized. This new approach developed to analyse the distribution of the signal intensities within the nucleus zone on T2-weighted images will be applied to quantitative MR mapping of relaxation times, magnetization transfer or diffusion parameters within the intervertebral disc.