Background

• If intervertebral disc degeneration can be identified early, preventative treatments may be initiated before symptoms become disabling and costly1-3.
• Clinicians currently rely on MRI grading to identify disc degeneration, but MRI is an unreliable indicator of symptomatic pathology in the spine4-6.
• Previous research indicates the hydrostatic nucleus becomes smaller and decompresses with age7. These mechanical changes are some of the earliest signs of degeneration8,9.
• The size and location of the functional nucleus (i.e. the disc region that undergoes little to no additional compression during dynamic loading) quantifies the changes in disc stiffness.

Aim

• Assess the potential for using in vivo dynamic disc deformation to identify pathologic structural degeneration in intervertebral discs.

Hypothesis

• Cervical spondylosis patients will display differences in size and location of the functional nucleus in the symptomatic degenerated discs compared to the asymptomatic controls.

Methods

Data Collection

• 30 participants consented to these two IRB approved studies: 10 with C5/C6 spondylosis (5M, 5F, age: 46.7±6.4 years), 10 with symptomatic C5/C6/C7 spondylosis (4M, 6F, age: 51.3±4.6 years) and 10 healthy adults (5M, 5F, age: 27.4±6.3 years).
• Participants performed 2-3 full flexion/extension trials and 2-3 axial rotation trials while biplane radiographs were collected (Figure 1 A, B).
• Disc degeneration was graded on pre-operative MRI for the spondylosis patients10.

Data Processing

• Bone kinematics were obtained using a previously validated volumetric model-based tracking system11 (Figure 1).
• The intervertebral discs were modeled as concentric, equidistant rings of line segments.
• The average relative compression of each line segment was found for each trial type during frames in which the vertebrae fell within half of the group average ROM (midrange motion).
• Line segments with less than 7% compressive strain12 from both flexion/extension and axial rotation were determined to be the functional nucleus (Figure 2).
• Functional nucleus area was normalized to endplate anterior/posterior (AP) depth and left/right (LR) width.

Data Analysis

• Between-group differences in size and location of the functional nucleus were identified using a Wilcoxon rank-sum test with significance set at p < 0.05.
• MRI correlation to functional nucleus parameters was evaluated using a Spearman’s correlation with significance set at p < 0.05.

Results

Functional Nucleus Size

• In the C5/C6 spondylosis patients, the C5/C6 functional nucleus had smaller AP depth (p = 0.012) and LR width (p = 0.016) compared to the controls (Figure 3C).
• In the C5/C6/C7 spondylosis patients, the C5/C6 and C6/C7 functional nucleus had smaller LR width (p = 0.015, p = 0.004), while the C6/C7 functional nucleus also had a smaller AP depth (p = 0.043) (Figure 3C,D).
• No differences in size were found at the adjacent levels in either the C5/C6 or C5/C6/C7 spondylosis patients (Figure 3A,B).
• No differences in size were found at the adjacent levels in either the C5/C6 or C5/C6/C7 spondylosis patients (Figure 3B).

Center Location

• The functional nucleus of the C5/C6 disc was more posterior compared to the controls in the C5/C6 spondylosis patients (p = 0.043).
• No differences were observed in the center location of the functional nucleus between C5/C6/C7 spondylosis patients and the controls.
• No differences in size were found at the adjacent levels in either the C5/C6 or C5/C6/C7 spondylosis patients (Figure 3B).

MRI correlation

• No association was found between MRI grading of disc degeneration and the size or location of the functional nucleus (all p < 0.34; all p > 0.103).

Discussion

• The differences in functional nucleus sizes provide preliminary evidence that structural disc degeneration may be identified from in vivo dynamic imaging in pathologic discs.
• The dynamic functional nucleus size was sensitive (significantly smaller than controls in 5 of 6 measurements at the diseased segment) and specific (no difference in 9 of the 10 measurements at non-diseased discs) for identifying pathological discs.
• The inability to find association between MRI disc degeneration and functional nucleus parameters may be due to the fact that MRI assesses static disc morphology and biology while functional nucleus parameters characterize dynamic response to loading.

• Strengths of this study include precise measurements of in vivo bone motion during flexion/extension and axial rotation.
• Limitations of this study include a small sample of 10 participants per group, and the lack of age-matched controls. However, the differences in the functional nucleus were primarily seen at the pathologic discs, suggesting the differences were due to structural degeneration and not simply aging.

Clinical Significance

• Dynamic imaging may be used to quantitatively identify pathologic disc degeneration.

References and Acknowledgements


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