Intervertebral disc changes in an animal model representing altered mechanics in scoliosis

+Stokes, IAF; 1McBride, CA; 1Aronsson, DD; 2Roughley PJ; 1University of Vermont, Burlington, VT; 2Shriners Hospital, Montreal, QC

Senior author Ian.Stokes@uvm.edu

INTRODUCTION:

The scoliosis deformity includes wedging of the vertebrae and of the intervertebral discs in approximately equal proportions. The pathomechanism of progressive deformity of the vertebrae and discs is poorly understood. Wedging and narrowing of discs may be due in part to an altered biomechanical environment. The eventual aim of this study is to determine how immature intervertebral discs respond morphologically, mechanically and biologically to the compression and angulation components of the altered mechanical environment that occurs in scoliosis. The purpose of the present study is to document morphological and biomechanical changes in four different models of altered mechanical environment in intervertebral discs of growing rats.

METHODS:

External rings attached by percutaneous pins transfixing adjacent vertebrae in 5-week-old Sprague-Dawley rats were applied for 5 weeks, using a modification of a published apparatus [1]. Four permutations of the altered mechanical environment (4 groups of animals, minimum 5 animals per group) were compared: 15 degrees Angulation (Group A), both Angulation and Compression (Group B), 0.1 MPa Compression (Group C), and Reduced mobility (Group D).

Angulation in Groups A and B was achieved by installing the rings each at 7.5 degrees to the transverse plane of adjacent tail vertebrae, then using connecting rods and springs to align the rings parallel to each other. Compression was achieved by compressing the springs to produce a force corresponding to 0.1 MPa [2]. All live animal procedures were IACUC approved.

RESULTS:

Geometrical: Disc narrowing at the intervention levels was evident in micro-CT images. In the first micro-CT scan (2 days post-instrumentation) compressed discs (groups B and C) had lesser disc space (mean 0.60 mm) than the uncompressed groups A and D (mean disc space 0.66 mm), representing 8.5% immediate narrowing in Groups B and C. There was further disc narrowing in all groups over the 5-week duration of the loading. Average disc narrowing as a percent of the initial values over the 5 weeks was 15%, 36%, 32% and 16% in the four groups. The amount of disc narrowing did not differ significantly between groups (p>0.05). Loss of disc space at control levels averaged 2% over the 5-week experiment.

Mechanical: Increased lateral bending stiffness relative to within-animal controls was observed in all groups. Stiffness averaged 55, 204, 51, 91 x 10^5 Nmm/deg in Groups A,B,C,D respectively. The minimum stiffness at distal control levels was 50 x 10^5 Nmm/deg. The minimum stiffness was recorded at an angle close to the in vivo value (mean angle less than 1 degree in all groups), indicating that angulated discs had adapted to the mechanically imposed scoliosis deformity.

Histology (Collagen crimping): At the intervention levels of the Group B (angulated and compressed) discs there was a small non-significant difference in the amount of collagen crimping in the disc annuli between concave and convex sides (mean crimp periods 28.3 and 29.6 ± 6.8 μm). This was consistent with the collagen having remodelled to a similar strain condition on each side of the angulated discs. The crimp periods at these levels was significantly less than at the within-animal control discs, where the crimp period averaged 38.7 μm. This is consistent with the fact that the intervention level discs were fixed with the apparatus in place, preventing swelling of the discs.

DISCUSSION:

All interventions (permutations of angulation, compression and reduced mobility) produced substantial changes in the intervertebral discs of these growing animals over the 5-week experiment. This 5-week period corresponded to a large proportion of the post-natal growth of the animals (bodyweight typically increased from 125 to 400 g). The changes included disc space narrowing and increased lateral bending stiffness, and there was evidence of collagen remodeling to accommodate the altered mechanical environment, also compatible with the observation that minimum lateral bending stiffness was measured close to the in vivo ‘bent-tail’ configuration in angulated discs.

‘Reduced mobility’ was present in all interventions, and the changes in the discs with reduced mobility alone were comparable with those in loaded and angulated discs. This suggests that reduced mobility is the major source of disc changes, and may be a factor in disc degeneration in scoliosis. Further studies are in progress to characterize gene expression, matrix protein synthesis and composition in these discs.

It is concluded that the 5-week growth period of these rats produces substantial disc tissue changes, probably comparable with secondary, biomechanically induced changes occurring during the adolescent growth phase in patients with scoliosis. Since the disc dimensions and properties were altered at the intervention levels of all four Groups, the reduced mobility that was present in all groups may be the major cause of the observed changes. The application of the rings and springs in Group D cannot be considered as a sham intervention, probably because it produces reduced mobility of the disc.

Acknowledgement This work made possible by grant NIH AR 053132.

REFERENCES: