THE GROWTH PLATE'S EFFECT ON THE MEASUREMENTS OF RAT-TAIL VERTEBRAL BIOMECHANICAL BEHAVIOUR

Hardisty MR, Skrinskas T, Akens M, Yee A, Whyne CM
Orthopaedic Biomechanics Laboratory, Sunnybrook Health Science Centre, University of Toronto, Toronto, ON
Michael R Hardisty,
UB-19, 2075 Bayview Ave, Toronto, ON, 416-480-5056, 416-480-5856, m.hardisty@utoronto.ca

Introduction: Rodents are often used as preclinical models for investigating the biomechanical consequences of spinal pathologies and interventions. Growth plates are present within rat vertebrae throughout life and may alter the vertebral biomechanics. This study investigates the biomechanical response of rat-tail vertebrae to axial compressive loading using μCT imaging and image registration to spatially resolve strain fields.

Methods: The 6th caudal vertebrae of 8 immunocompromised (rnu/rnu) rats were μCT scanned (17.5 ×17.5 ×17.5μm/pixel) in both loaded (27N-32N axial compression) and unloaded configurations. The specimens were loaded with a custom designed μCT compatible device. Image registration was used to calculate strain and displacement fields in bone due to applied load. The registration was implanted in a multi-resolution framework. The algorithm begins with an iterative optimization of affine mapping parameters (consisting of rotation, scaling, shearing and translation, 12 DOF) to ideally match the loaded and unloaded scans based upon the mutual information contained in the 2 images. Once an acceptable fit was obtained, the moving scan was partitioned into 8 pieces by bisecting along the 3 axes. These 8 pieces formed the second level of registration; each was individually registered. The affine transform found for registering the whole moving scan was used as the initial guess in these eight sub-pieces. They each spawn eight more individual pieces and so on until the maximum level of analysis was reached. Once the registration completed, the displacement and strain fields were calculated:

$$e = \frac{1}{2}\left(\nabla\vec{A}^{T} + \nabla\vec{A}\right) \qquad \vec{A}(x,y,z) = \tilde{T}(x,y,z)P(x,y,z) - P(x,y,z)$$

Where e is the strain matrix, A is the displacement, T is the affine transform found from registration and P is the voxel location. The strain at the centre of registration regions was calculated by finite differencing; elsewhere the field was interpolated with 3rd order B-splines.

Results: Axial strains calculated by image registration ranged from 2% in tension to 16% in compression with an average axial strain of 1.6% in compression. In 7 rats the majority of strain in the vertebrae was concentrated in growth plates. Very soft growth plates in 3 specimens resulted in max axial strains from 10-16% in compression. The remaining 4 rats had thinner growth plates with strain concentrations in the growth plate had max axial strains ranging from 2.2%-3.2. Centrally located strain concentrations of low magnitude and more limited spatial extent were observed in trabecular bone.

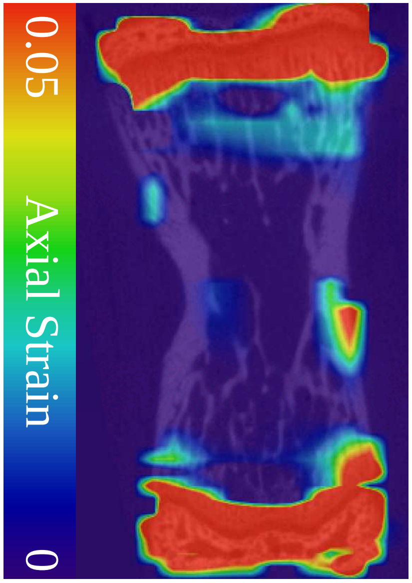

Figure 1: Sagittal cut of a μCT scan of the unloaded vertebrae coloured with magnitude of compressive strain in the vertical direction (ε_{zz}) as calculated by the image registration algorithm. The strain is due to axial compressive loading.

Conclusions: The growth plates absorbed the majority of the strain within the rat vertebrae. The amount of strain within the growth plate is important to consider when interpreting biomechanical data on rat vertebrae. Load application to rodent vertebrae will first compress the growth plate and only following compression of this structure cause significant development of displacement and strain in trabecular and cortical bone. This insight into the biomechanical response of rat vertebrae is apparent through the application of image registration to analyse vertebral body behaviour; such information would not be evident in analysing preclinical whole vertebral body response using finite element modeling or experimental testing protocols.