Research paper

Relationships between viscoelastic properties of lumbar intervertebral disc and degeneration grade assessed by MRI

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A B S T R A C T

Biomechanical modelling of the spine is of high clinical significance, either for implant evaluation or for surgery planning. Nevertheless, assessment of patient specific material properties still remains an issue, especially the viscoelastic characteristics of lumbar intervertebral discs (IVD). MRI, a dedicated system for IVD examination, provides a signal that is correlated with the biochemical content of the disc. Since IVD composition and its mechanical properties are related, the objectives of this study were to investigate how MRI could inform about viscoelastic properties of lumbar discs, determined from creep experiments. For that purpose, an in vitro protocol was carried out regarding 14 human L1–L2 IVDs; each unfrozen specimen was imaged using MRI and biomechanically tested with 10 min creep under 400 N load. Three-parameter rheologic models were used to fit the experimental curves. Additionally, geometry was obtained and degeneration was assessed using both MRI grading and physical inspection (destructive analysis). Mean creep displacement was 0.19 mm after 10 min. MRI scaling categorized elastic modulus and viscosity of the IVDs in 2 clearly distinct groups without overlaps according to degeneration: mean values for elastic modulus were 12.9 MPa and 5.7 MPa, respectively for mildly and severely degenerated IVDs; mean values for viscosity were 5.7 GPa s and 2.2 GPa s, respectively for mildly and severely degenerated IVDs. Classification derived from physical inspection did not reveal a clear discrimination. MRI could hence provide a quantification of IVDs viscoelastic properties, leading to in vivo direct estimation of material characteristics necessary for patient specific modelling.

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1. Introduction

Low back pain often originates in mechanical disorders, such as osteoarthritis or degenerative disc disease. Intervertebral discs (IVDs) are complex structures composed of distinct elements (annulus fibrosus, nucleus pulposus, cartilaginous endplates) integrated into functional spinal units (FSUs) in order to provide both mobility and stability to the vertebral column. Though able to sustain high load magnitudes in various directions according to the individual posture, IVDs...