Author's Accepted Manuscript

www.elsevier.com/locate/jmbbm

A three-dimensional micromechanical model of brain white matter with histology-informed probabilistic distribution of axonal fibers

Seyed Abdolmajid Yousefsani, Farzam Farahmand, Amir Shamloo

PII: S1751-6161(18)30797-5
DOI: https://doi.org/10.1016/j.jmbbm.2018.08.042
Reference: JMBBM2953

To appear in: *Journal of the Mechanical Behavior of Biomedical Materials*

Received date: 21 May 2018
Revised date: 17 August 2018
Accepted date: 28 August 2018

A three-dimensional micromechanical model of brain white matter with histology-informed probabilistic distribution of axonal fibers

Seyed Abdolmajid Yousefsani, Farzam Farahmand*, Amir Shamloo

Mechanical Engineering Department, Sharif University of Technology, Azadi Avenue, Tehran, Iran

Abstract

This paper presents a three-dimensional micromechanical model of brain white matter tissue as a transversely isotropic soft composite described by the generalized Ogden hyperelastic model. The embedded element technique, with corrected stiffness redundancy in large deformations, was used for the embedment of a histology-informed probabilistic distribution of the axonal fibers in the extracellular matrix. The model was linked to a multi-objective, multi-parametric optimization algorithm, using the response surface methodology, for characterization of material properties of the axonal fibers and extracellular matrix in an inverse finite element analysis. The optimum hyperelastic characteristics of the tissue constituents, obtained based on the axonal and transverse direction test results of the corona radiata tissue samples, indicated that the axonal fibers were almost thirteen times stiffer than the extracellular matrix under large deformations. Simulation of the same tissue under a different loading condition, as well as that of another white matter tissue, i.e., the corpus callosum, in the axonal and transverse directions, using the optimized hyperelastic characteristics revealed tissue responses very close to those of the experiments. The results of the model at the sub-tissue level indicated that the stress concentrations were considerably large around the small axons, which might contribute into the brain injury.

Keywords: Hyperelastic Characterization; Embedded Element Technique; Large Deformation; Multi-Objective Optimization

* Correspondence to: Mechanical Engineering Department, Sharif University of Technology, Azadi Avenue, Tehran, Iran. Tel: +98 (21) 66165532, Fax: +98 (21) 66000021.
E-mail: farahmand@sharif.edu (F. Farahmand)