3D micromechanical homogenization of brain tissue considering random neuronal distribution within the extracellular matrix

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Abstract

A micromechanical model is developed on a Representative Volume Element (RVE) of the brain integrating anisotropic neuron distribution to simulate its mechanical behavior under different loading conditions. The RVE is defined using the different following parameters: size of RVE, number of neurons, radius of the neuron cellular volume, coordinates of the axon and dendrites of a neuron, radius of the axon and dendrites and the minimum distance between the cellular volumes. The creation of the RVE is performed using a PYTHON code and imported into the ABAQUS ® FE software. The homogenization of the random neurons distribution in the extracellular matrix is developed through a MATLAB code to avoid collision between cells and is used as inputs for the finite element analysis. The material behaviors for the different components of the brain tissue are considered elastic-viscoelastic [1-4]. The elastic and viscoelastic material parameters are employed from [1, 5], respectively. In the analyses, the effects of Neuron Volume Fraction (NVF), strain rate loading and neurons distribution were investigated on the mechanical behavior of the RVE brain tissue. Three relaxation tests were conducted with NVF of 1%, 2% and 3%. Results show that the local maximum stresses in the loading directions increased with increasing NVF. Equivalent homogenized mechanical properties were found, irrespective of the VER neurons distribution. The VER size was therefore optimized for sizes of 300 μm, 400 μm, 700 μm, 900 μm and 1100 μm with a 1.5% NVF. It was found that an RVE size of 900 μm is a suitable choice for an equivalent corresponding homogenized behavior compared with experimental and theoretical observations [6].

Keywords : Micromechanical modeling, Brain tissue, Neuron, Extracellular matrix, Representative Volume Element (RVE).

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