BRAIN CAPILLARY GEOMETRY DEVELOPMENT FOR MULTISCALE MODELLING STUDY

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Abstract

Due to low spatial resolution of functional magnetic resonance imaging (fMRI), mathematical modelling of human brain is usually developed in ischaemic stroke study in order to enhance the understanding of ischaemic stroke mechanism so that proper treatment plan can be decided to a particular stroke patient. A 3D brain geometry is developed in this project using AutoLISP, which is a programming language within AutoCAD. The objective of this project is to re-create the geometry developed by El-Bouri et al. by replacing the 1-dimensional line with 3-dimensional capillary which can be meshed for the simulation. Simulation of blood flow using Stokes' cell equation is done in the 3D geometry in order to obtain effective hydraulic conductivity, K. Finally, the hydraulic conductivity obtained from the simulation is analysed and compared with previous work done by El-Bouri et al. Based on result in section 3, the initial geometry developed is further modified by adding few small cylinders and also bigger volume of the geometry with 15.21% percentage difference. Non-diagonal elements obtained in matrix K show non-zero values due to small voxel size used for the simulation (180μm), which should be increased to more than 250μm. The percentage difference of diagonal elements K_{11}, K_{22}, and K_{33} are 8.05%, 2.65% and 21.43% respectively. The large percentage differences are probably due to additional volume added to the 3D geometry to maintain its periodicity with neighbouring voxels. Besides, meshing process and mesh size chosen are also contributing factor to the large percentage difference between both hydraulic conductivity values.

1 Introduction

Ischaemic stroke occurs when the blood supply to the brain is interrupted or blocked, preventing brain tissue from receiving sufficient oxygen and nutrients [1]. According to Sharma et al., there are two types of ischaemic stroke; thrombosis and embolism [2]. Approximately 50% of all stroke cases are thrombosis strokes, which occurs when the arteries of the brain are blocked by blood clots in the brain or neck. Embolism stroke is caused by a blood clot formed in another part of the body (often from the heart), moving along with the blood flow and get stuck in the arteries of the brain [3]. When tissue is cut off from its supply of oxygen for more than three or four minutes, it begins to die. The region of inadequate blood perfusion in the brain can be visualised with functional magnetic resonance imaging (fMRI) [4]. However, low spatial resolution of this imaging approach and its inability to detect inadequate perfusion in micro capillaries make it impossible to understand blood perfusion at the tissue level [5].

Based on data from Cassot and Lauwers (2006) [6], El-Bouri et al. has developed continuum model of blood flow in a capillary network model of the human cortex in order to understand the blood perfusion at the tissue level [7]. Stokes' cell problem was solved by El-Bouri et al. in a geometry proposed by Su et al. to obtain the hydraulic conductivity (K) [8]. In the geometry, brain capillaries are represented by 1-dimensional (1D) lines which cannot be meshed in the simulation. Thus, the geometry cannot be used to solve remaining microscale parameters such as homogenous Biot's coefficient, Young's modulus and Poisson's ratio.

This project aims to create a 3-dimensional (3D) capillary geometry of the brain microvasculature using programmable computer assisted drawing (CAD) based on the work by El-Bouri et al. Instead of using 1D line as in previous work, 3D cylinder will be used in this project to represent the capillary so that the geometry can be properly meshed and used for the simulation. Stokes' cell equation will be solved in the developed geometry to obtain hydraulic conductivity. Finally, the outcome of the simulation will be compared with the findings reported by El-Bouri et al. for further verification and analysis of the 3D geometry.

2. Methodology

The methodology section will describe the structure of the brain capillary data and the process to import the data into AutoCAD through AutoLISP environment. Then, the process to convert the 1D geometry into 3D using AutoCAD will be