Integrated Mathematical Modeling and Advance Visualization of Magnetic Nanoparticle for Drug Delivery, Drug Release and Effects to Cancer Cell Treatment

Authors : Norma Binti Alias, Che Rahim Che The, Norfarizan Mohd Said, Sakinah Abdul Hanan, Akhtar Ali

Abstract : This paper discusses on the transportation of magnetic drug targeting through blood within vessels, tissues and cells. There are three integrated mathematical models to be discussed and analyze the concentration of drug and blood flow through magnetic nanoparticles. The cell therapy brought advancement in the field of nanotechnology to fight against the tumors. The systematic therapeutic effect of Single Cells can reduce the growth of cancer tissue. The process of this nanoscale phenomena system is able to measure and to model, by identifying some parameters and applying fundamental principles of mathematical modeling and simulation. The mathematical modeling of single cell growth depends on three types of cell densities such as proliferative, quiescent and necrotic cells. The aim of this paper is to enhance the simulation of three types of models. The first model represents the transport of drugs by coupled partial differential equations (PDEs) with 3D parabolic type in a cylindrical coordinate system. This model is integrated by Non-Newtonian flow equations, leading to blood liquid flow as the medium for transportation system and the magnetic force on the magnetic nanoparticles. The interaction between the magnetic force on drug with magnetic properties produces induced currents and the applied magnetic field yields forces with tend to move slowly the movement of blood and bring the drug to the cancer cells. The devices of nanoscale allow the drug to discharge the blood vessels and even spread out through the tissue and access to the cancer cells. The second model is the transport of drug nanoparticles from the vascular system to a single cell. The treatment of the vascular system encounters some parameter identification such as magnetic nanoparticle targeted delivery, blood flow, momentum transport, density and viscosity for drug and blood medium, intensity of magnetic fields and the radius of the capillary. Based on two discretization techniques, finite difference method (FDM) and finite element method (FEM), the set of integrated models are transformed into a series of grid points to get a large system of equations. The third model is a single cell density model involving the three sets of first order PDEs equations for proliferating, quiescent and necrotic cells change over time and space in Cartesian coordinate which regulates under different rates of nutrients consumptions. The model presents the proliferative and quiescent cell growth depends on some parameter changes and the necrotic cells emerged as the tumor core. Some numerical schemes for solving the system of equations are compared and analyzed. Simulation and computation of the discretized model are supported by Matlab and C programming languages on a single processing unit. Some numerical results and analysis of the algorithms are presented in terms of informative presentation of tables, multiple graph and multidimensional visualization. As a conclusion, the integrated of three types mathematical modeling and the comparison of numerical performance indicates that the superior tool and analysis for solving the complete set of magnetic drug delivery system which give significant effects on the growth of the targeted cancer cell.

Keywords : mathematical modeling, visualization, PDE models, magnetic nanoparticle drug delivery model, drug release model, single cell effects, avascular tumor growth, numerical analysis
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