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Research Article

Mathematical Based Calculation of Drug Penetration Depth in Solid Tumors

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Cancer is a class of diseases characterized by out-of-control cells' growth which affect cells and make them damaged. Many treatment options for cancer exist. Chemotherapy as an important treatment option is the use of drugs to treat cancer. The anticancer drug travels to the tumor and then diffuses in it through capillaries. The diffusion of drugs in the solid tumor is limited by penetration depth which is different in case of different drugs and cancers. The computation of this depth is important as it helps physicians to investigate about treatment of infected tissue. Although many efforts have been made on studying and measuring drug penetration depth, less works have been done on computing this length from a mathematical point of view. In this paper, first we propose phase lagging model for diffusion of drug in the tumor. Then, using this model on one side and considering the classic diffusion on the other side, we compute the drug penetration depth in the solid tumor. This computed value of drug penetration depth is corroborated by comparison with the values measured by experiments.

1. Introduction

Chemotherapy is an important option for cancer treatment which uses chemical substances (anticancer drug) to fight cancer. Considering application of drug through blood stream, drug travels to the cancer tumor and diffuses in it through capillaries as is shown in Figure 1.

Drug concentration in the tumor is dependent on drug production (supply, release, and activation), transport (diffusion and advection), and elimination (decay, deactivation, and cellular intake) [1]. These processes involve various biochemical, mechanical, and biophysical factors which make the process complex. Mathematical modeling provides a mean to better understand this complexity. Also mathematical modeling allows scientists to link the laboratory experiments with clinical applications by providing the means to extrapolate the in vivo results from mouse models to humans. There are valuable attempts in modeling of steps which affect drug concentrations, which have been reported in the literature. We can call the mathematical/computational models addressing drug vascular supply [2–6], drug release and activation [7–13], drug diffusive transport [14–24], drug advective transport [5, 25–27], and drug decay, deactivation, and cellular uptake [28–31].

In chemotherapy, it is also important that drug reaches the entire tumor, otherwise its effectiveness will be compromised [32]. So, in chemotherapy, a minimum effective concentration is required in all parts of the tumor for the effective treatment. One of the factors that come to account in discussion about drug concentration is drug penetration depth in the tumor. Penetration depth can be defined as the depth from a capillary at which the minimum concentration (required for cancer treatment) is achieved. Thus, studying and measuring the drug penetration depth in solid tumor are important issues in chemotherapy.

Beside numerous experimental studies which have been done on measuring the drug penetration depth in solid tumors [33–37], limited works on mathematical modeling