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Biophysical Modeling of Anisotropic Brain Tumor Growth

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Abstract : Solid tumors have high interstitial fluid pressure (IFP), high mechanical stress, and low oxygen levels. Solid stresses may induce apoptosis, stimulate the invasiveness and metastasis of cancer cells, and lower their proliferation rate, while oxygen concentration may affect the response of cancer cells to treatment. Although tumors grow in a nonhomogeneous environment, many existing theoretical models assume homogeneous growth and tissue has uniform mechanical properties. For example, the brain consists of three primary materials: white matter, gray matter, and cerebrospinal fluid (CSF). Therefore, tissue inhomogeneity should be considered in the analysis. This study established a physical model based on convection-diffusion equations and continuum mechanics principles. The model considers the geometrical inhomogeneity of the brain by including the three different matters in the analysis: white matter, gray matter, and CSF. The model also considers fluid-solid interaction and explicitly describes the effect of mechanical factors, e.g., solid stresses and IFP, chemical factors, e.g., oxygen concentration, and biological factors, e.g., cancer cell concentration, on growing tumors. In this article, we applied the model on a brain tumor positioned within the white matter, considering the brain inhomogeneity to estimate solid stresses, IFP, the cancer cell concentration, oxygen concentration, and the deformation of the tissues within the neoplasm and the surrounding. Tumor size was estimated at different time points. This model might be clinically crucial for cancer detection and treatment planning by measuring mechanical stresses, IFP, and oxygen levels in the tissue.

Keywords : biomechanical model, interstitial fluid pressure, solid stress, tumor microenvironment
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