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Complex Dynamics and Bifurcation Analysis of a Virotherapy Model

Recent progress in genetic engineering has led to a new way to treat cancer called virotherapy. It uses modified viruses that attack and kill cancer cells while leaving healthy cells unharmed. Oncolytic virotherapy utilizes viruses to partic- ularly target and destroy cancer cells, offering a novel and increasingly studied cancer treatment approach. The mathematical model describing the interaction among un- infected tumor cells, virus-infected cells, and virus particles is formulated as a system of nonlinear ordinary differential equations and analyzed in the following work. The model captures essential biological processes such as logistic tumor growth, virus- mediated infection, cytolysis, and viral clearance. We perform a comprehensive bifurcation analysis to understand the system's dynamic behavior under varying biological parameters. Using center manifold theory and normal form analysis, we identify con- ditions for a codimension of Hopf bifurcation, revealing the emergence of stable limit cycles that represent sustained oscillatory dynamics between tumor cells and viral populations. Our results provide theoretical insights into the origins and nonlinear mechanisms that govern successful virotherapy, offering valuable guidance for the optimization of treatment procedures in clinical and experimental settings.