Fractional-Order Modeling and Neural Network Learning for Oncolytic Virotherapy Dynamics

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Abstract

Oncolytic virotherapy has emerged as a promising cancer treatment strategy that utilizes engineered viruses to selectively infect and destroy tumor cells. This work presents a discrete fractional-order mathematical framework to investigate the complex interaction among cancer cells, infected tumor cells, natural killer (NK) cells, and oncolytic viruses. The proposed model incorporates memory effects through fractional-order operators, allowing a more realistic representation of immune response and viral dynamics over time. Analytical properties of the model, including positivity, boundedness, equilibrium analysis, and stability conditions, are established using fractional difference theory and fixed-point techniques. The basic reproduction number is derived and sensitivity analysis is performed to identify influential biological parameters governing treatment effectiveness. Numerical simulations demonstrate the critical balance between viral replication and NK cell activation required for successful tumor suppression. In addition, an artificial neural network approach is trained using generated numerical data to efficiently approximate the system dynamics and provide fast predictive capability. The results highlight the potential of combining fractional calculus and machine learning tools to improve understanding and optimization of modern cancer immunotherapy strategies.

Keywords

Oncolytic virotherapy, fractional-order systems, mathematical modeling, artificial neural networks, cancer dynamics.