Viral kinetics modulates immuno-epidemiological dynamics: insights from a multiscale PDE model

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Abstract

Viral kinetics depend on the interactions between the virus and immunity. They regulate viral shedding, infection time, and recovery rates. In this work, we extend a susceptible-infected-recovered-susceptible (SIRS) model by integrating viral load dynamics using a partial differential equation (PDE) approach. In this model, infected individuals are structured according to the level of the virus and immunity, allowing the integration of viral kinetics using a divergence term. Susceptible individuals are stratified according to immunity levels to account for immune waning and possibility of reinfection. The framework is parameterized according to the viral, immunological and epidemic characteristics of acute and chronic diseases. We analyze the impact of changes in viral kinetics on the epidemic dynamics. Subsequently, we reduce our model to a simplified compartmental ordinary differential equation (ODE)-based model that incorporates the population-level viral kinetics. We aim through our work to demonstrate and establish a modeling approach which is applicable to the forecast of diseases through wastewaters surveillance and collection.