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A deterministic model for influenza infection with multiple strains and antigenic drift

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We describe a multiple strain Susceptible Infected Recovered deterministic model for the spread of an influenza subtype within a population. The model incorporates appearance of new strains due to antigenic drift, and partial immunity to reinfection with related circulating strains. It also includes optional seasonal forcing of the transmission rate of the virus, which allows for comparison between temperate zones and the tropics. Our model is capable of reproducing observed qualitative patterns such as the overall annual outbreaks in the temperate region, a reduced magnitude and an increased frequency of outbreaks in the tropics, and the herald wave phenomenon. Our approach to modelling antigenic drift is novel and further modifications of this model may help improve the understanding of complex influenza dynamics.

Keywords: influenza; antigenic drift; cross-immunity; multiple strains; seasonality

AMS Subject Classification: 92D30; 92D15

1. Introduction

Influenza presents a significant morbidity and mortality burden in the world; a typical seasonal influenza epidemic kills up to 49,000 people per year [5] in the USA, and from a quarter to half a million worldwide [27]. One of the key aspects of the influenza virus is its ability to reinfect hosts. Influenza is an RNA virus and lacks a proofreading mechanism for its polymerase. As a consequence, it is prone to mistakes every time a copy of its genome is made. Since these mutations usually do not change how the virus is identified by the immune system, an infection with one influenza strain generally confers lasting immunity to an identical strain. However, if the virus has undergone sufficient significant changes in its surface proteins, then reinfection with influenza is possible. This process is termed antigenic drift. One of the main findings on this topic is that the immunity conferred after infection wanes with decreasing relatedness between the immunizing and challenging strains [7]. Thus, once a few years have passed since the previous infection with a specific subtype of influenza, a human host may become almost completely susceptible to the currently circulating grand-daughter strain [7].

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