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Stability analysis of a fractional order model for the HIV/AIDS epidemic in a patchy environment

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Abstract

A multi-patch HIV/AIDS epidemic model with fractional order derivative is formulated to investigate the effect of human movement on the spread of HIV/AIDS epidemic among patches. We derive the basic reproduction number R_0 and prove that if $R_0 < 1$, the disease-free equilibrium (DFE) is locally and globally asymptotically stable. In the case of $R_0 > 1$, we obtain sufficient conditions under which the endemic equilibrium is unique and globally asymptotically stable. We also formulate a fractional optimal control problem (FOCP), in which the state and co-state equations are given in terms of the left fractional derivatives. We incorporate into the model time dependent controls aimed at controlling the spread of HIV/AIDS epidemic. The necessary conditions for fractional optimal control of the disease are obtained. The simulation of the model is done with two patches. The numerical results show that implementing all the control efforts decreases significantly the number of HIV-infected and AIDS people in both patches. In addition, the value of R_c, the control reproduction number, for a long time is at its minimum level, and the value of objective functional J(u) increases when the fractional derivative order α is reduced from 1 ($0.8 \leq \alpha \leq 1$).

Keywords: Patchy environment, Fractional optimal control, Diseases modeling, Global stability

1. Introduction

Human immunodeficiency virus (HIV), which leads to acquired immunodeficiency syndrome (AIDS), is a pandemic which is almost very dangerous and fatal if untreated and uncontrolled. Over 35 million people have died from AIDS-related illnesses since the start of the epidemic in 1981. According to the latest UNAIDS data, as of June 2016 about 18.2 million people living with HIV were accessing antiretroviral therapy (ART). AIDS-related deaths globally have decreased by 26% since 2010, from an estimated 1.5 million in 2010 to

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