May 30th, 10:30 AM - 11:00 AM

Staged HIV Transmission and Treatment in a Dynamic Model with Concurrency

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HIV progression studies have asserted three stages: acute infection, chronic infection, and AIDS. We develop a model with three stages and include an infection class with non-uniform Highly Active Anti-Retroviral Treatment leading to viral suppression. Capturing the incidence rate of HIV in minority U.S. women requires a model stratified by race/ethnicity and sexual behavior in addition to assumptions of assortative partner choice and concurrent relationships. We include the effect of concurrency following the work of Watts and May (1992, Math. Biosciences) who in a simple deterministic model allowed for overlapping partnerships and infection from either a new sexual partner or a longtime partner who was uninfected at the start of the partnership. This model was hampered by the assumption of a latent phase which generated a non-autonomous system. We present a new autonomous deterministic model of the effect of concurrent sexual partnerships that allows for an analytical study of disease transmission. We incorporate the effect of concurrency through the newly derived force of infection term in a mathematical model of the transmission of HIV through sexual contact in a population stratified by sexual behavior and race/ethnicity. Time series analysis, as well as parameter sensitivity analysis, determine which strategy has the largest impact in the short and long term. Interventions focused on encouraging chronically infected into viral suppression, as well as interventions focused on maintaining viral suppression have the largest impact on the long term dynamics, and the latter having the largest impact on the heterosexual community due to current racial disparity in treatment. While reducing concurrency likelihood and duration positively impacts the long term dynamics, left unchecked, an increase in concurrency will significantly raise the values of the endemic equilibrium.