Control policies for dengue: insights from a mathematical model

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Abstract. We propose a mathematical model to study the dynamics of dengue fever in a susceptible population. Our main goal is to assess the effect of four different control strategies: existence of sterile male mosquitoes, use of pesticides for larvae, and for adult mosquitoes, and vaccination, in the disease propagation. We discuss the results of numerical simulations from an epidemiological point of view. Inferences on health policy measures are drawn.

Introduction

Dengue is a mosquito-borne viral infection, caused by the dengue virus (DENV) of the *Flaviviridae family*. Dengue incidence has seen a pronounced increase in recent decades. Dengue prevention and control depends on effective vector control measures. These encompass combat mosquito vectors, with the prevention of mosquito breeding, community engagement, reactive vector control, and active mosquito and virus surveillance. Vaccination is also an important prevention strategy.

The proposed model

$$\begin{array}{rcl}
A_m' &=& \phi_1\left(1-\frac{A_m}{C}\right)(F_2+F_4)-(\sigma_A+\mu_A)A_m,\\
F_1' &=& p\sigma_A A_m-\frac{\beta}{M_1+M_2}F_1M_1-\frac{\beta}{M_1+M_2}F_1M_2-\mu_mF_1,\\
F_2' &=& \frac{\beta}{M_1+M_2}F_1M_1-\frac{b\beta_m}{H+m}H_iF_2-\mu_mF_2,\\
F_3' &=& \frac{\beta}{M_1+M_2}F_1M_2-\mu_mF_3,\\
F_4' &=& \frac{b\beta_m}{H+m}H_iF_2-\mu_mF_4,\\
M_1' &=& (1-p)\sigma_A A_m-\mu_mM_1,\\
M_2' &=& \phi_2-\mu_mM_2,\\
H_s' &=& \mu_h(H-H_s)-\frac{b\beta_h}{H+m}H_sF_4+\eta H_r,\\
H_e' &=& \frac{b\beta_h}{H+m}H_sF_4-(\theta_h+\mu_h)H_e,\\
H_i' &=& \theta_hH_e-(\alpha_h+\mu_h)H_i,\\
H_r' &=& \alpha_hH_i-(\eta+\mu_h)H_r,
\end{array}\qquad (1)$$

where A_m-mosquito's aquatic phase, F_1-uninfected and unmated female mosquito, F_2- uninfected fertilized female mosquito, F_3-uninfected mated fertilized female, F_4-infected mating fertilized female, M_1-normal male mosquito, M_2-sterile male mosquito, H_s-susceptible human, H_e-exposed human, H_i-infectious human, H_r-recovered human. Vaccination, $v(t)$, is added as follows. The term $-v(t)H_s(t)+kv(t)H_r(t)$ is added to $H_s(t)$ and subtract from $H_r(t)$. Parameter k represents the waning immunity process.

Results and discussion

In Figure 1, we depict the effect of the four control strategies in the dynamics of dengue spread for the normal male mosquitoes (M_1) and for the infected humans populations (H_i). The results are promising, since they show decrease in the number of normal male mosquitoes and infected humans. Dengue is still a major concern worldwide, with a 70% actual burden in Asia. Epidemiologists can provide substantial advise to policy makers by interpreting the predictions provided by mathematical models.

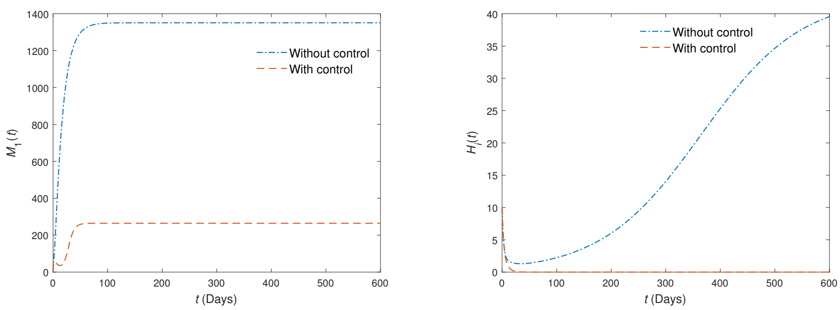

Figure 1: The effect of the four control strategies on the dengue model (1).

References

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