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Original Research Article

On the role of HIV/AIDS support groups on combating new infections

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ABSTRACT

Aim: Since its emergence in the 1980s, the human immunodeficiency virus (HIV), the causative agent of the acquired immune deficiency syndrome (AIDS), remain a major challenge to the global health and human development. We explore the role of optimal HIV counseling and support groups on combating new infections.

Background: The stigma surrounding HIV/AIDS makes life more difficult for people living with HIV/AIDS and their families. People living with HIV/AIDS needs a lot of emotional, spiritual, psychological, social, physical and clinical support. During voluntary HIV testing and counseling detected individuals are encouraged to become a member of an HIV/AIDS support group where they will receive useful information on how to live positively.

Methods: Mathematical model have become invaluable management for epidemiologists, both shedding light on mechanisms underlying observed dynamics as well as making quantitative predictions on the effectiveness of different control measures. Here, we propose a deterministic HIV model that incorporates HIV counseling and support groups. After qualitative analysis the model is extended to incorporate optimal control theory. The objective function minimizes the population of infectious individuals unaware of their HIV status and infectious individuals aware of their HIV status but are reluctant to completely desist from risk sexual activities. The optimal control is characterized and solved numerically for several cases.

Results: Qualitative analysis of the proposed model show that voluntary HIV testing and HIV/AIDS support groups have a positive impact on effective control or elimination of the disease. It is shown that in the presence of time dependent HIV testing and support groups more reduction of new infections is achieved. For instance, if more effort and resource are availed on voluntary HIV testing than on support groups, then after a period of twenty years then the population of individuals unaware of their HIV status will decrease by more than fifty percent.

Conclusion: With regard to voluntary HIV counseling and support groups results in this study provide a frame work for designing cost-effective strategies for effective control of HIV in the absence of HIV therapy.

1. Introduction

The stigma surrounding HIV/AIDS presents a formidable challenge to people living with the disease and their families. Thus, people living positive to HIV need a lot of emotional, spiritual, psychological, social, physical and clinical support in order to overcome a number of challenges they face such as loneliness, anxiety, stress, confusion, bitterness, depression and so on [1]. Once an individual tested positive to HIV, health experts encourage the individual to become a member of an HIV/AIDS support group. There are different types of support groups, such as support groups that meets at a clinic, support groups that meet at church premises, house gatherings, letter witting and buddy system to mention a few. Although, different people and different institutions can provide some support, it has been observed that it is essential for people living with the disease to come together and support one another [2], since they would know better their hopes, joy, anxieties, fears and needs. More often people living with HIV/AIDS are encouraged to become a member of a support groups that meets in a clinic or hospital where a doctor, nurse or social worker usually runs these support groups [1].

In this paper, our objective is to formulate a model for HIV/AIDS that includes relevant biological detail, accounts for voluntary HIV testing and counseling, and allows optimal control methods to be used. To begin, we integrate the aforementioned essential components into one SIA-type (susceptible-infectious-AIDS patients)

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model to accommodate the diverse dynamics of HIV transmission. To model the effect of voluntary HIV testing and counseling, we partition the infectious populations into three compartment: infectious individuals unaware of their HIV status, sexual active infectious individuals aware of their HIV status, and sexual inactive infectious individuals aware of their HIV status. After fundamental mathematical analysis, we extend our initial model to include two control functions, each representing a possible method of HIV intervention. The first control function represents the efforts on initial voluntary HIV testing and counseling (that is, encouraging people to become aware of their HIV status), while the second models the impact of HIV/AIDS support groups on slowing down the spread of the disease by individuals aware of their status. Using optimal control theory and numerical simulations, we determine the effectiveness of the aforementioned intervention strategies. A brief discussion of rounds up the paper. It is worth stating that the model does not incorporate HIV therapy.

This work is motivated by the current global HIV statistics which states that at the end of 2012, 35.3 million people had tested positive to the disease, with 69% (24. 4 million) of these infections from Sub-Saharan Africa [3]. Further analysis of the World Health Organization report of 2012 suggests that of the 69% HIV infected individuals, about 39.8% (9.7 million) of these people had access to antiretroviral therapy. The vast majority of HIV infected people in developing countries are unable to access life-saving treatment for the disease and its related opportunistic infections. The obstacles are associated with high cost of drugs and poor health infrastructure [3]. Based on this information we found it relevant to explore the effectiveness of time dependent voluntary HIV testing and counseling in the absence of HIV therapy.

2. Methods and results

2.1. Model framework

In this section, we present an ordinary differential equation (ODE) version of a model for the spread of HIV in human population. The total population size at time t, given by $N(t)$, is partitioned into subclasses of individuals who are susceptible $S(t)$, infectious and sexual active individuals unaware of their HIV status, $I_u(t)$, infectious and sexual active individuals aware of their HIV status $I_a(t)$, infectious and sexual inactive individuals aware of the HIV status $I_w(t)$, and the sexual inactive AIDS patients $A(t)$. Thus,

$$N(t) = S(t) + I_u(t) + I_a(t) + I_w(t) + A(t).$$

New individuals are recruited at rate Π and are assumed to be susceptible to the disease. Assuming homogeneous mixing of the populations it follows that the susceptible individuals acquire HIV infection through risk sexual activities at rate:

$$\lambda = \frac{\beta_u I_u + \beta_a I_a}{N}.$$

The parameter β_i ($i = u, a$) denotes the HIV transmission rate. It is defined as the product of the probability of HIV transmission per contact and the contact rate effective for the disease transmission to occur. Thus, β_u and β_a denote HIV transmission of individuals in class I_u and I_a, respectively. Furthermore, we assume that $\beta_a \le \beta_u$, since individuals aware of their HIV status may practice safe sex through the use preventive measures (such as condom use) or reduction on the number of sexual partners, which in turn may contribute to reduction in HIV spread. It is worth noting that, in some instances individuals aware of their HIV status may derive the epidemic due to a couple of reasons such as loss of hope and lack of necessary precautions. The host population dies at a natural death rate μ. In addition, AIDS patients succumb to disease-related mortality at rate δ. HIV individuals progress to AIDS stage at rates ϕ,

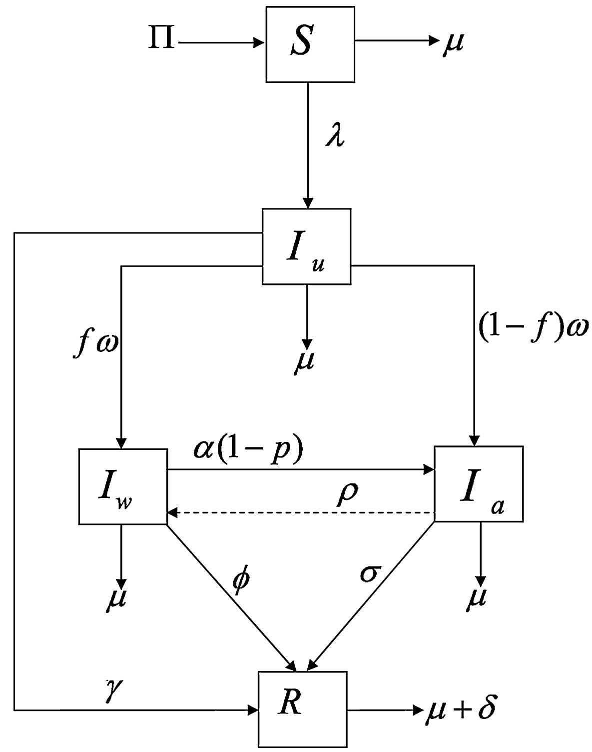

Fig. 1. Model flow diagram.

σ, and γ for individuals in class I_w, I_a and I_u, respectively. HIV individuals becomes aware of their status at rate ω. Upon being aware of their status, a fraction f is assumed to withdraw from risk sexual activity and the remainder $(1-f)$ is assumed to continue engaging in risk sexual activity, however, with reduced chances of either infecting or being infected. During voluntary HIV testing and counseling detected individuals are encouraged to become a member of an HIV/AIDS support group where they will receive useful information on how to live positively. We assume that participation of infectious individuals in HIV/AIDS support groups can encourage those who are still engaging in risk sexual activities to quit. Thus, infectious individuals in class I_a transfer to class I_w at rate ρ. Further, we assume that a fraction $(1-p)$ of HIV infected individuals who would have withdrawn from risk sexual activities may relapse into risk sexual activities at rate α and this may be influenced by a number of reasons which include losing hope, peer influence and so on. HIV transmission dynamics in this population are governed by the following system of nonlinear ODEs:

$$\left.\begin{aligned}
\dot{S} &= \Pi - \lambda S - \mu S,\\
\dot{I_u} &= \lambda S - (\omega + \mu + \gamma) I_u,\\
\dot{I_a} &= (1-f)\omega I_u + \alpha(1-p) I_w - (\mu + \sigma + \rho) I_a,\\
\dot{I_w} &= f\omega I_u + \rho I_a - (\alpha(1-p) + \mu) I_w,\\
\dot{A} &= \gamma I_u + \sigma I_a + \phi I_w - (\mu + \delta) A,
\end{aligned}\right\} \tag{1}$$

where the upper dot represents the derivative of the component with respect to time. The dynamical transfer of the population are demonstrated in Fig. 1.

2.2. Analysis of the HIV compartmental model

For biological reasons we study the solutions of system (1) in the closed set:

$$\Omega = \left\{ (S, I_u, I_a, I_w, A) \in \mathbb{R}^5_+ : N \le \frac{\Pi}{\mu} \right\}.$$