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Control and Cost-benefit Analysis of Fast Spreading Diseases: The case of Ebola

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Introduction

Mitigating the spread of infectious disease is of great importance for policy makers. Taking the recent outbreak of Ebola as an example, it was difficult for policy makers to identify the best course of action based on the cost-effectiveness of what was available.

In effort to address the needs of policy makers to mitigate the spread of infectious disease before an outbreak becomes uncontrollable, we have devised a cost-benefit disease control model to simulate the effect of various control methods on disease incidence and the cost associated with each of the scenarios. Here, we present a case study of Ebola used to quantify the cost effectiveness of vaccination and isolation methods to minimize the spread of the disease. We evaluate the impact of changing strategy levels on the incidence of the disease and address the benefits of choosing one strategy over the other with regards to cost of vaccine and isolation.

Methods

Disease. We use a general SEIRJ model for disease transmission. Here, S-Susceptible, E- Exposed (latent), I_A – Infected (asymptomatic), I_M – Infected (mild symptoms), I_S – Infected (severe symptoms), J_M – Isolated (mild symptoms at home), J_S – Isolated (severe symptoms in hospital), and R- Recovered individuals. In this model, we consider the dynamics of the system and the effect of the relative transmissibility of isolated individuals (L) compared to other infected individuals[1].

Cost. Ebola vaccination and treatment are very expensive and not widely available. Some preliminary data shows that it will take $73 million (M) to produce 27 M vaccines[2] plus the cost for vaccine delivery and health care professionals (not included here). On the other hand, the treatment for Ebola in the U.S. would cost $25,000 dollars a day per person[3] to ensure proper isolation and adequate care (treatment, health care professionals, facilities and special equipment). Although not included in this research, the proper isolation of Ebola patients would also lead to a loss in hospital revenue of $148,000 per day due to reduced patient capacity[3]. Here, we use $27,000 per individual hospitalized per day and $2.70 per person vaccinated.

Model. To evaluate the cost-effectiveness of control methods on disease transmission, we assessed the affect of different levels of vaccination coverage on the resulting number of infected individuals. Then, we calculated the overall estimated cost of vaccination and resulting hospitalization for each scenario to identify the lowest cost-benefit ratio.

Results

Using a base population of 10 M individuals, we ran scenarios for different levels of vaccination ($\mu = 0.01, 0.05, 0.1$) while varying the relative transmissibility of isolated individuals (L = 0.5, 0.6, 0.65). For each combination, we calculated the incidence, vaccination and hospitalization cost per individual per day (Fig 1). We note that an increase in the relative transmissibility of isolated individuals leads to a higher number of infected people and, therefore, a reduced number of candidates for vaccination and an overall increase in cost. Since the cost of vaccination is 1 ten-thousandth of the cost of hospitalization, our results clearly show the cost-benefit of vaccinating over hospital treatment. In every scenario studied, we observed a measurable reduction in disease incidence when vaccinating a higher fraction of the population compared to isolating individuals post infection.

Conclusions

Given these preliminary results, we plan to extend the framework of our model to a dynamic control system where we consider the cost of vaccination and isolation embedded in the system of differential equations. This approach will allow us see the best available control implementation while minimizing the cost of treatment and vaccination.
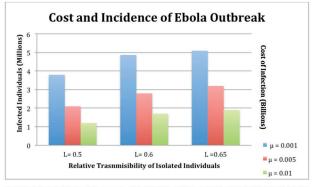

Figure 1: The incidence for different vaccination coverage (μ = 0.001, 0.005, 0.01) and relative transmissibility of isolated individuals (L= 0.5, 0 .6, 0.65). Infected individuals are represented in Millions while the cost of isolation is in Billions of dollars.

Keywords

Control; Epidemiological Modeling; Transmission Dynamics; Cost; EBOLA

References

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