Vaccination strategies impact the probability of outbreak extinction: A case study of COVID-19 transmission

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Rationale and objective: Various vaccination strategies have been employed throughout history to control infections and terminate outbreaks. However, most prior modeling studies have predominantly centered on vaccine allocation strategies categorized by age groups (e.g., teenagers, working-age adults, and seniors) to explore the most effective vaccination approaches for reducing deaths, cases, hospitalizations, or years of life lost. Until now, there has been a noticeable gap in research focusing on the impact of vaccination strategies on the extinction of outbreaks. In this study, we, therefore, aimed to investigate the influence of various vaccination strategies on the probability of outbreak extinction, using COVID-19 transmission as a case study. We proposed vaccination strategies based on infection and mortality risks rather than relying solely on age classification. Besides, we examined the impact of vaccination strategies on infections and deaths. Furthermore, we analyzed the effect of the waning vaccine effectiveness on change in the probability of disease extinction and disease transmission dynamics.

Summary: In this study, we utilized the transmission of COVID-19 as a case study and constructed a stochastic age-structured compartmental model to investigate the effectiveness of different vaccination strategies. Our analysis focused on estimating the outbreak extinction probability under different vaccination scenarios in homogeneous and heterogeneous populations. Notably, we found that population heterogeneity can enhance the likelihood of outbreak extinction at varying levels of vaccine coverage. Prioritizing vaccinations for individuals with higher infection risk was found to maximize outbreak extinction probability and reduce overall infections while allocating vaccines to those with higher mortality risk has been proven more effective in reducing deaths. Moreover, our study highlighted the significance of booster doses as the vaccine effectiveness wanes over time, showing that they can significantly enhance the extinction probability and mitigate disease transmission.

Outcome: Our modeling results indicated that vaccination strategies affect the probability of outbreak extinction and the reduction in the number of cases and deaths. We found that the infection-risk priority vaccination strategy could enhance the extinction probability and mitigate the cumulative cases. To reduce the number of deaths, both mortality-risk priority and mortality-risk weighted vaccination strategies provide better results. However, the infection-risk priority might be a suitable strategy for constraining disease transmission and alleviating both cases and deaths under the high vaccine effectiveness scenario.

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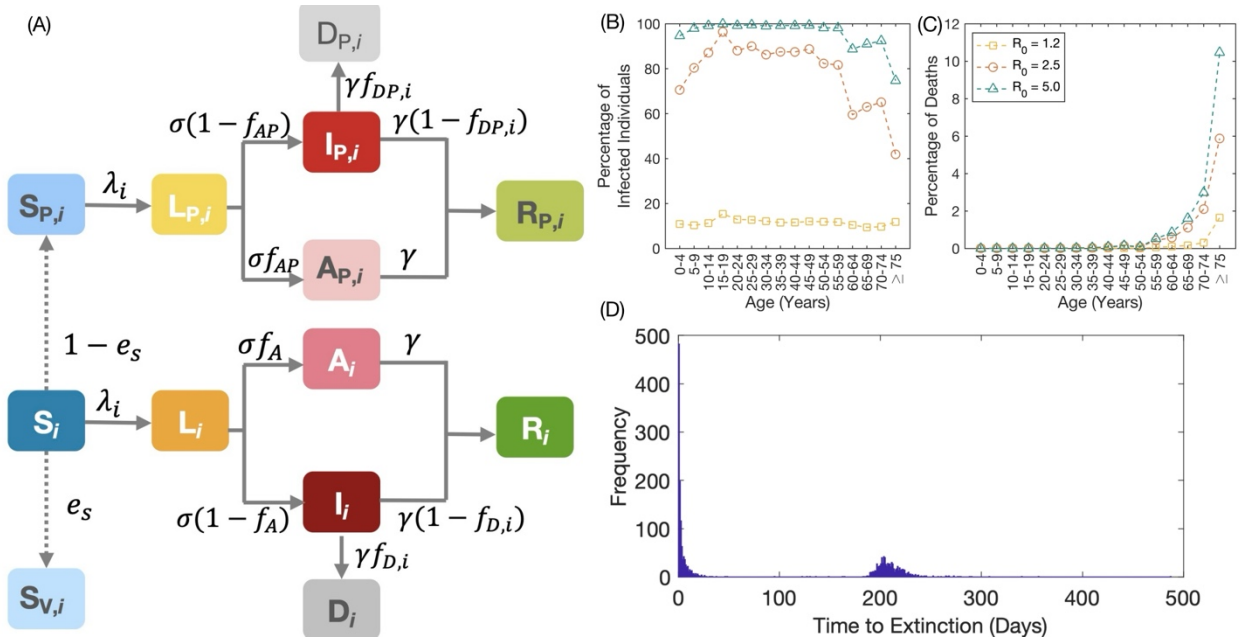
Related SDGs goal: 3. Good health and well-being.



Graphical summary: Illustration of the COVID-19 transmission model and simulation parameters. (A) A schematic representation of the compartmental model showing the progression of the disease and transition of individuals across different compartments. The solid lines show the transition between two compartments. (B) and (C) The infection risk and the mortality risk at different values of R_0. (D) The frequency of extinction obtained from 2000 model realizations.

Related publication:

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