Calculating vaccination targets for Covid-19

Sahel Mohammad Iqbal

NISER

June 7, 2021

Primary reference

- L. Matrajt, J. Eaton, T. Leung, and E. R. Brown. Vaccine optimization for covid-19: Who to vaccinate first? *Science Advances, 7(6), 2021.* DOI: 10.1126/sciadv.abf1374. [1]

SCIENCE ADVANCES | RESEARCH ARTICLE

CORONAVIRUS

Vaccine optimization for COVID-19: Who to vaccinate first?

Laura Matrajt[1]*, Julia Eaton[2†], Tiffany Leung[1†], Elizabeth R. Brown[1,3]

Vaccines, when available, will likely become our best tool to control the COVID-19 pandemic. Even in the most optimistic scenarios, vaccine shortages will likely occur. Using an age-stratified mathematical model paired with optimization algorithms, we determined optimal vaccine allocation for four different metrics (deaths, symptomatic infections, and maximum non-ICU and ICU hospitalizations) under many scenarios. We find that a vaccine with effectiveness ≥50% would be enough to substantially mitigate the ongoing pandemic, provided that a high percentage of the population is optimally vaccinated. When minimizing deaths, we find that for low vaccine effectiveness, irrespective of vaccination coverage, it is optimal to allocate vaccine to high-risk (older) age groups first. In contrast, for higher vaccine effectiveness, there is a switch to allocate vaccine to high-transmission (younger) age groups first for high vaccination coverage. While there are other societal and ethical considerations, this work can provide an evidence-based rationale for vaccine prioritization.

Table of contents

Motivation

- As vaccines become available, what distribution strategy should we choose?
- To which age groups should we give the vaccine, and in what proportions, in order to bring the pandemic under control?

Table of contents

Compartmentalized models

- Authors use what is known as a compartmentalized model.
- The population is divided into groups such as Susceptible (S), Infected (I), Hospitalized (H), Vaccinated (V) and so on.
- A person can jump from one compartment to the other with probabilities that depend on variuos parameters specific to the disease under consideration, such as
  - The reproduction number R
  - The latency period
  - The fatality and recovery rates

Compartmentalized models

- Pair the model with an optimization function that seeks to minimize some loss function or metric.
- Authors tried to minimize four different metrics.
- Deaths, symptomatic infections, non-ICU and ICU hospitalizations.

Details of the model

- Run the model without anyone vaccinated. This is the control.
- Run the model with a certain number of vaccine available of a given efficacy.
- Compare the outputs of both in terms of the metrics outlined earlier.

Methodology

- Used a mathematical model paired with optimization algorithms to determine the optimal use of vaccine for 100 combinations of VE and number of doses available under a wide variety of scenarios.
- State-level model with population size similar to Washington and demographics similar to those of the general US population.

Assumptions

- Both natural and vaccine-induced immunity last at least 1 year (duration of the model).
- At the beginning of the simulation, some percentage of the population have already been infected and are immune (calculations for 10, 20, 30 and 40).
- Social distancing norms have been lifted.
- Front line health-care workers and other essential personal (e.g. police) have already been vaccinated.

Details of the mathematical model

- 16 age groups grouped into 5 vaccination groups based on current knowledge of disease severity and mortality based on age.

Table of contents

Results

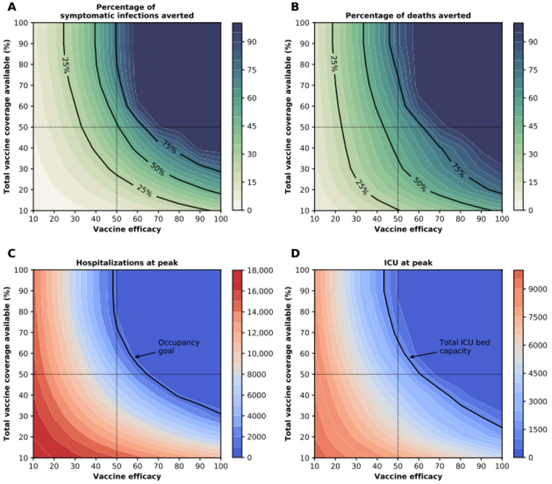

Figure: Key metrics under optimal distribution of vaccines.

Results

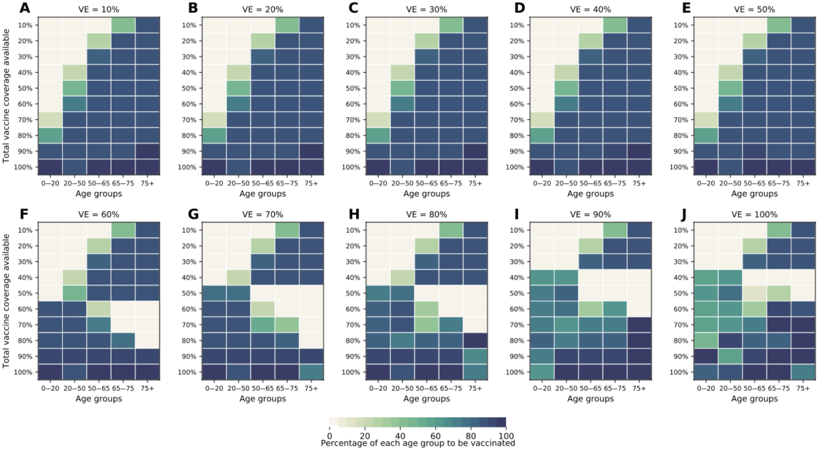

Figure: Optimal allocation strategies to minimize deaths for different VE.

Results

- For low vaccine effectiveness, it is optimal to allocate vaccines to high-risk (older) age groups first.
- In contrast, for higher vaccine effectiveness, there is a switch to allocate vaccine to high-transmission (younger) age groups first for high vaccination coverage.

Results

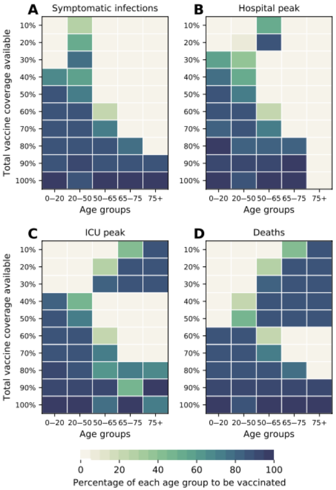

Figure: Optimal allocation strategies for different objective functions.

Table of contents

Limitations

- Has four different independent optimization criteria, but in reality we may need a combination of all four with different priorities assigned to each.
- Does not include racial, ethnic and economic divides, which play a crucial role in the evolution of epidemics [2].
- The assumptions mentioned earlier, of which particularly important is the unreasonably large proportion of initially immune people.

Conclusions

- Despite the limitations, this study provides good insight into the vaccination process for administrators.
- Can be easily modified and adapted to better suite local conditions.

L. Matrajt, J. Eaton, T. Leung, and E. R. Brown.
Vaccine optimization for covid-19: Who to vaccinate first?
Science Advances, 7(6), 2021.

S. Sze, D. Pan, C. R. Nevill, L. J. Gray, C. A. Martin, J. Nazareth, J. S. Minhas, P. Divall, K. Khunti, K. R. Abrams, L. B. Nellums, and M. Pareek.
Ethnicity and clinical outcomes in COVID-19: A systematic review and meta-analysis.
EClinicalMedicine, 29-30:100630, 2020.