Model-informed COVID-19 vaccine prioritization by age and serostatus

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There are two main approaches to vaccine prioritization.

Direct protection: vaccinate the most vulnerable

Indirect protection/herd immunity*: vaccinate those who have the most contacts

*assuming the vaccine blocks infection or transmission upon infection

There are two main approaches to vaccine prioritization.

Direct protection: vaccinate the most vulnerable

Indirect protection/herd immunity*: vaccinate those who have the most contacts

➔ Are there general principles for when to use a direct vs indirect protection approach?

Specifically, we're focused on how to prioritize initial doses within a country when

1. Supplies are limited
2. Relevant parameters are unknown/uncertain (e.g. VE, duration of NPIs, vaccine rollout speed, amount of ongoing transmission)

Our approach:

Use an age-structured SEIR model to measure the impact of prioritization strategies on

- ➔ Cumulative incidence
- ➔ Mortality
- ➔ Years of life lost

Model considerations

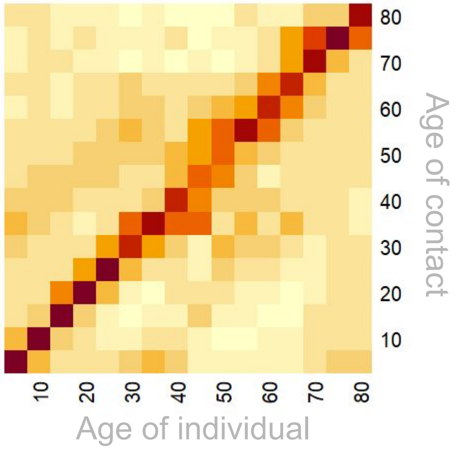
Disease Dynamics:

- Age-varying susceptibility [Davies]
- Age-varying infection fatality rate [Levin]

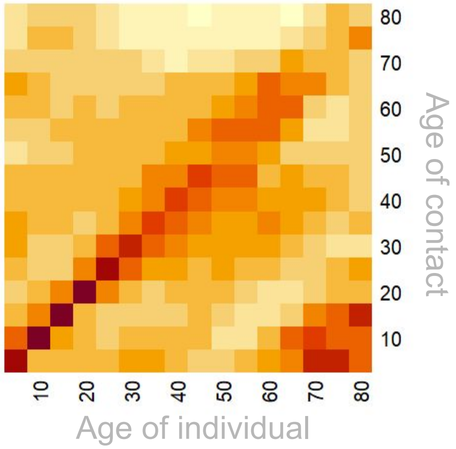
Population structure:

- Country-specific contact matrices [Prem]
- Country-specific age demographics [UNWPP]
- Seroprevalence by age [Bajema, New York]

Germany



Zimbabwe



Model considerations

Distribution:

- Rollout speed
- Number of available doses
- 30% vaccine hesitancy [Gallup survey]

Vaccine properties:

- Overall efficacy
- Possible decrease in efficacy by age
- Three models for efficacy

Three models for vaccine efficacy

Let's suppose that the vaccine has VE = 90%.

Model 1: the vaccine provides full protection from infection to 9 in 10 people. [1 in 10 get no protection.]

Model 2: the vaccine provides 90% protection from infection to everyone.

Model 3: the vaccine reduces clinical disease by 90%, and affects infection and transmission to a varying degree.

Three models for vaccine efficacy

Let's suppose that the vaccine has VE = 90%.

Model 1: the vaccine provides full protection from infection to 9 in 10 people. [1 in 10 get no protection.]

All-or-nothing VE

Model 2: the vaccine provides 90% protection from infection to everyone.

Leaky VE

Model 3: the vaccine reduces clinical disease by 90%, and affects infection and transmission to a varying degree.

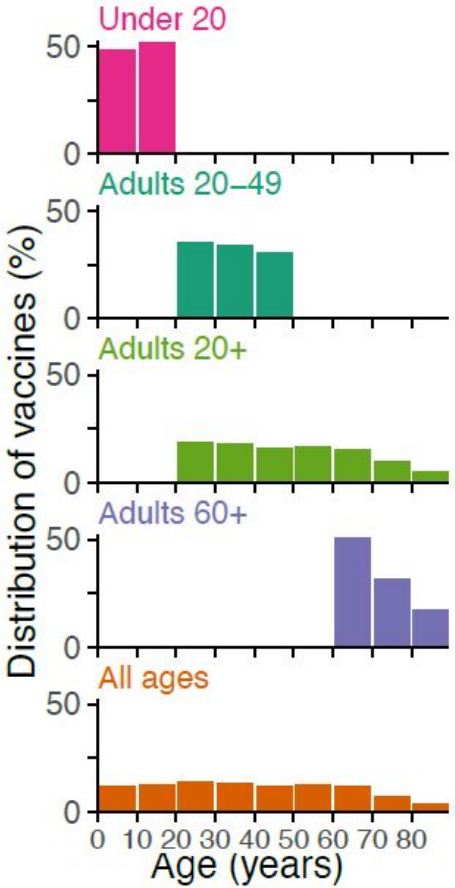
Variable transmission blocking VE

➔ We implemented all three to see if the modeling choice changed results. For Pfizer/Moderna, Model 3 is the most realistic.

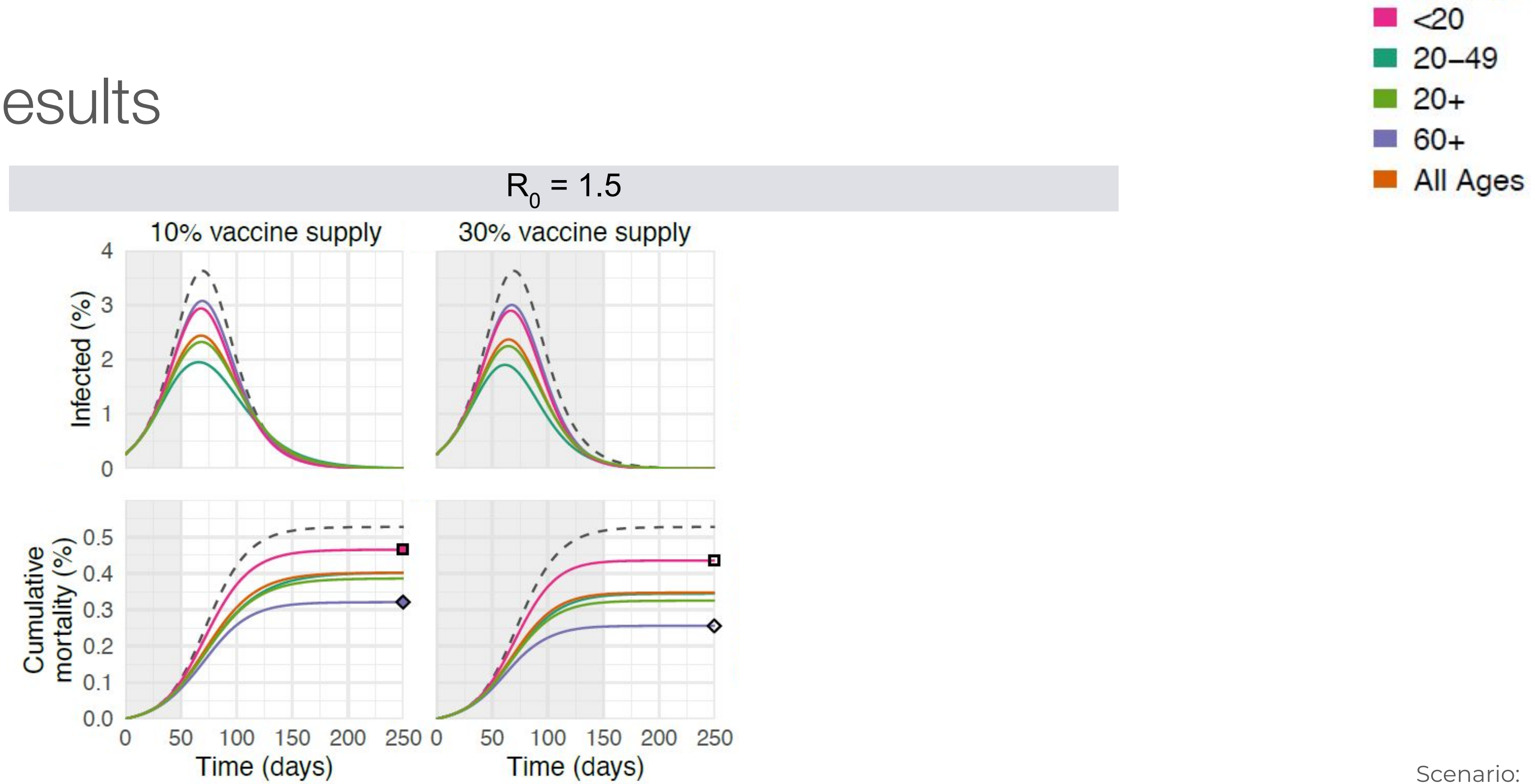
Prioritization strategies

We consider 5 straightforward prioritization strategies by age.

After all eligible prioritized individuals have been vaccinated, remaining doses are distributed randomly to the rest of the population.

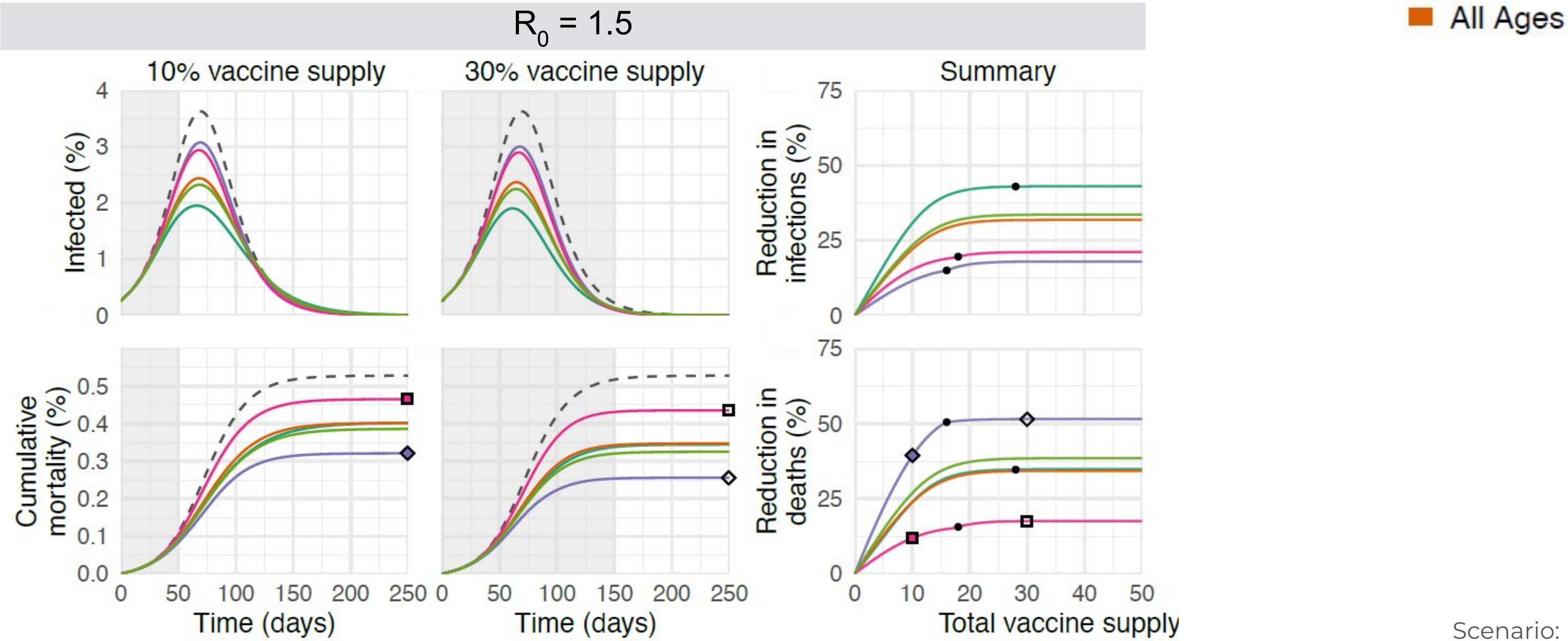


Results



Scenario:
US, 0% sero+
rollout = 0.2%/day
All-or-nothing, 90% ve
Transmission blocking
30% vaccine hesitant

Results



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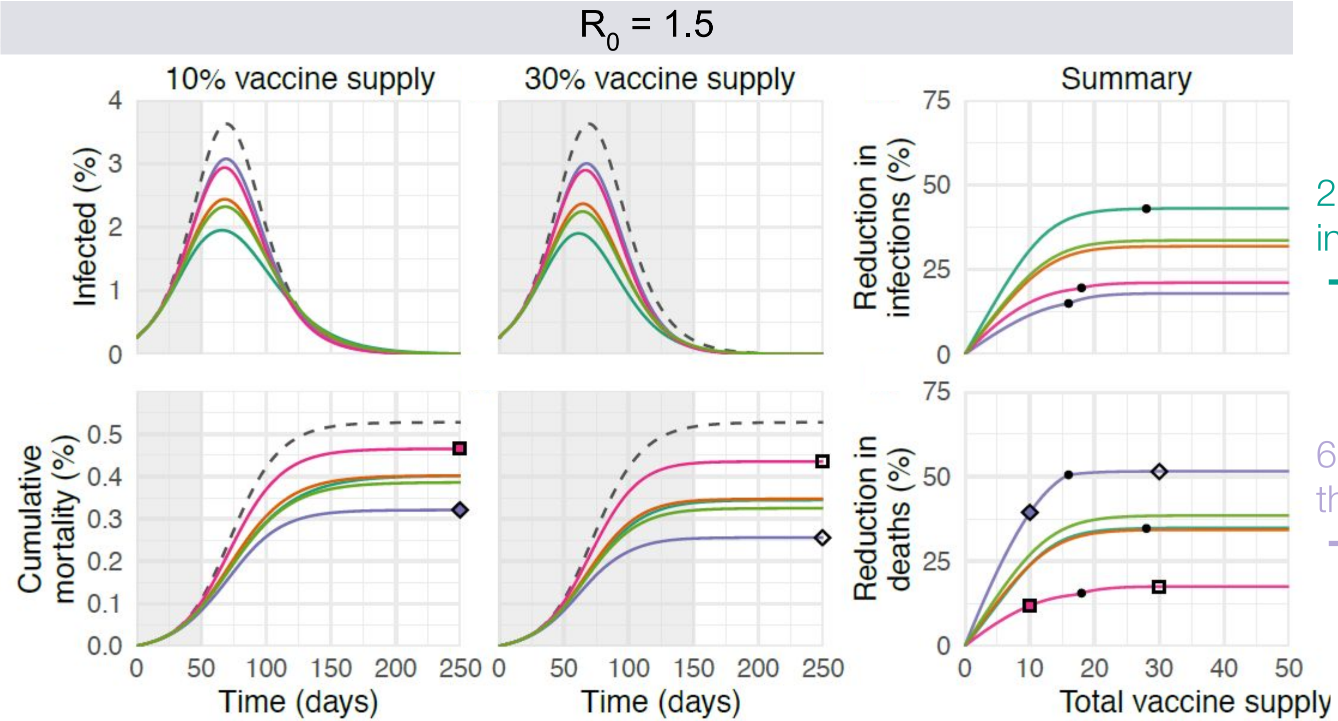

20-49 reduces infections the most
➔ Indirect protection approach

60+ reduces morality the most
➔ Direct protection approach

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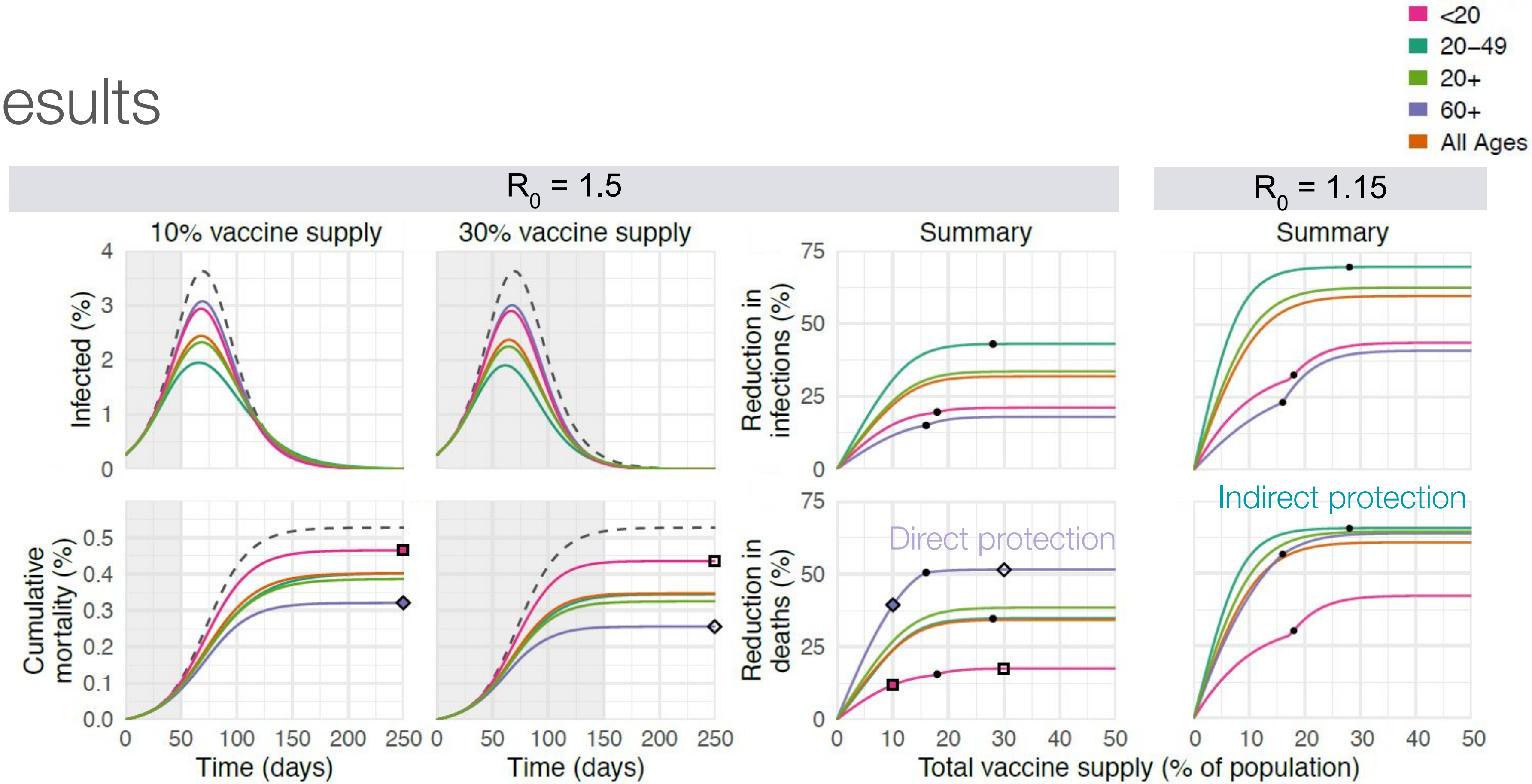
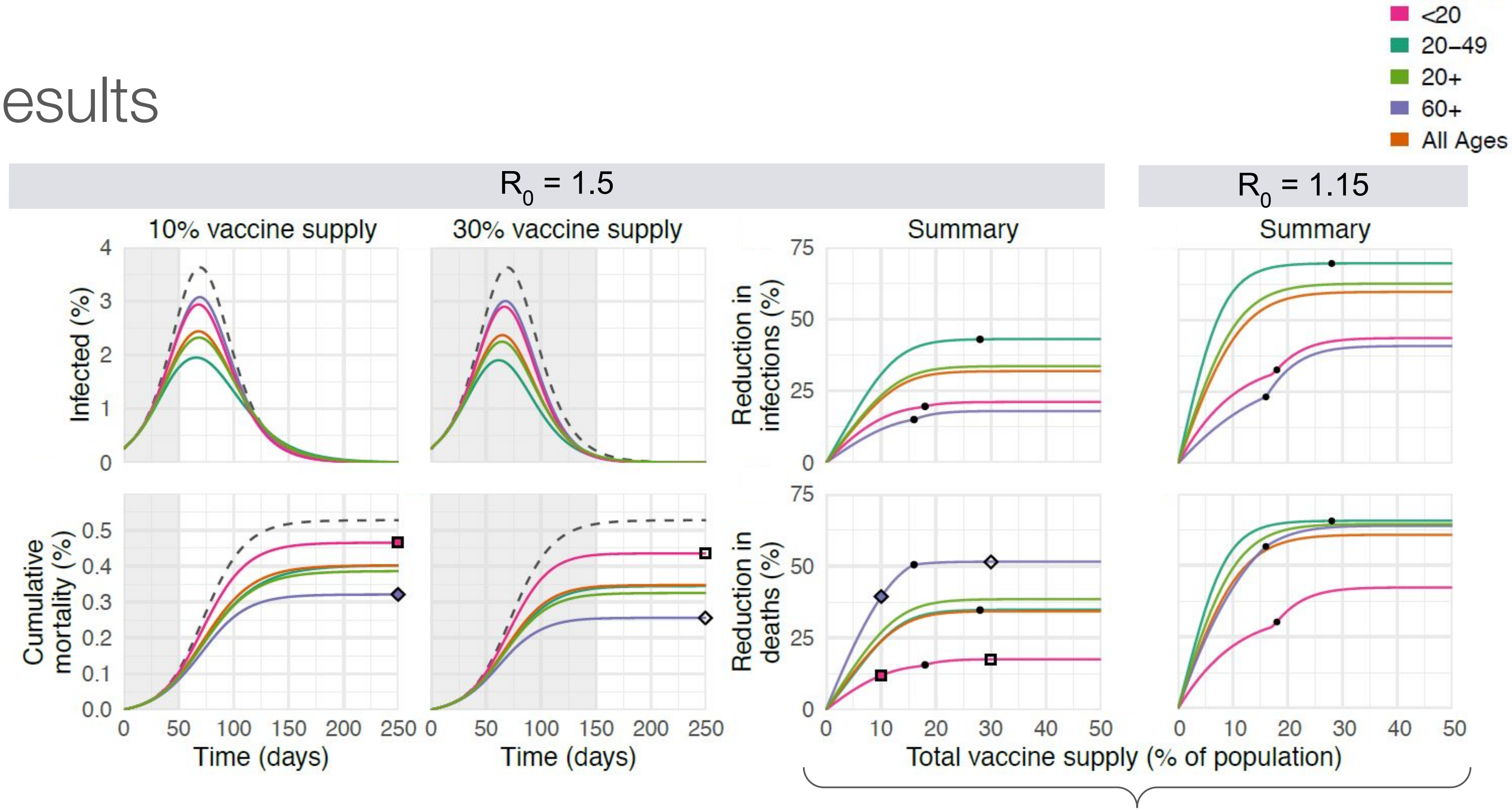
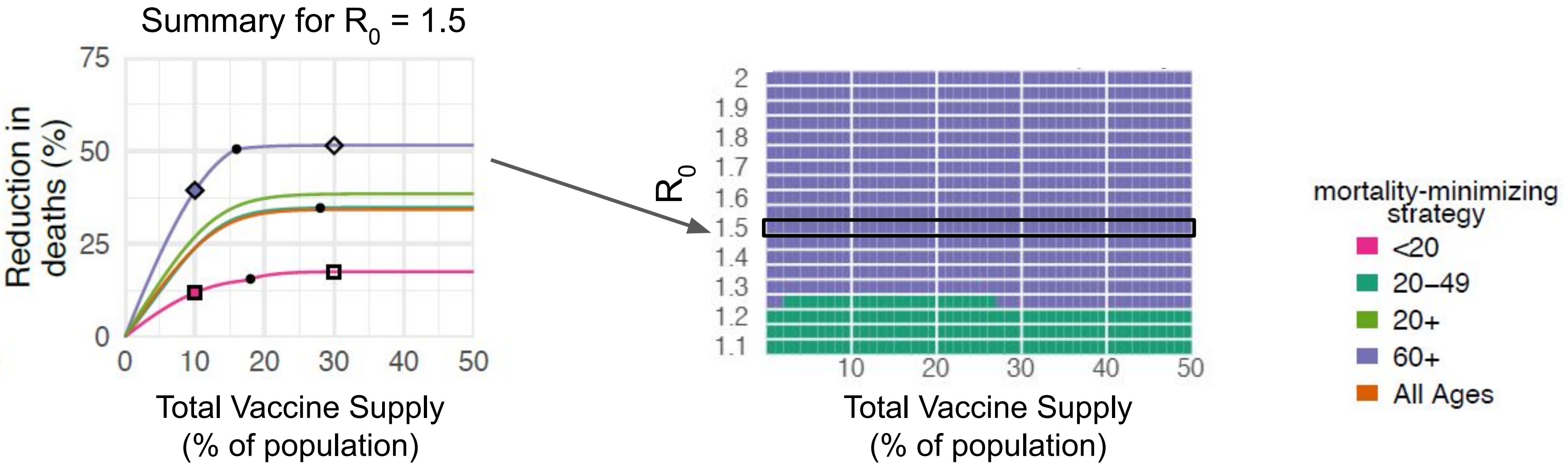

<20
20–49
20+
60+
All Ages
R0 = 1.5
R0 = 1.15
10% vaccine supply
30% vaccine supply
Summary
Summary
Infected (%)
Cumulative mortality (%)
Reduction in infections (%)
Reduction in deaths (%)
Direct protection
Indirect protection
Time (days)
Time (days)
Total vaccine supply (% of population)

Results



We want to know how sensitive these results are to different parameters

Sensitivity analysis



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Transmission blocking

Does prioritization depend on the timing and speed of distribution? What about R_0?

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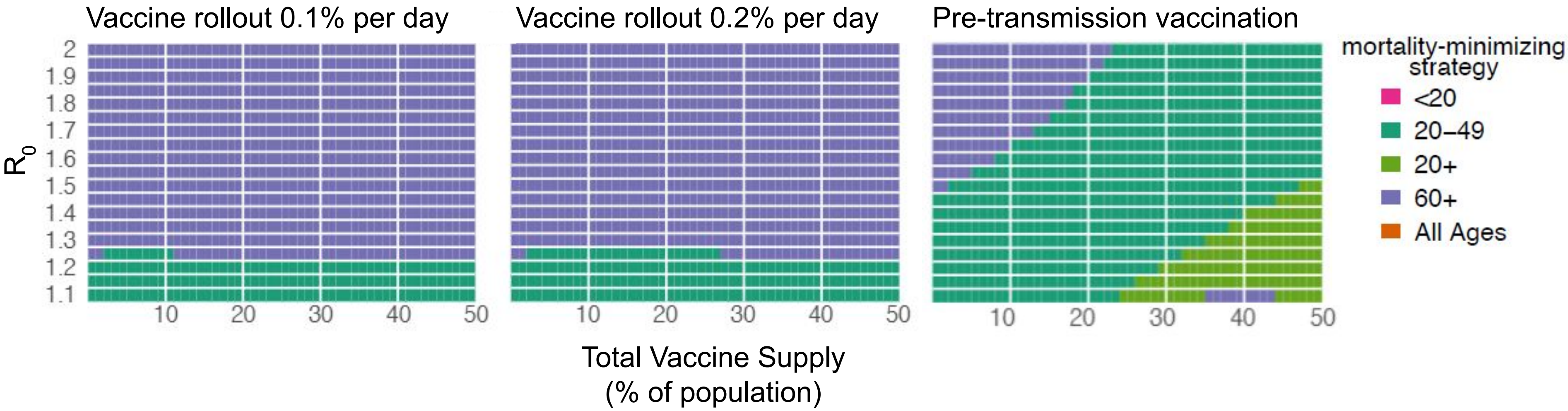

Scenario:
US, 0% sero+
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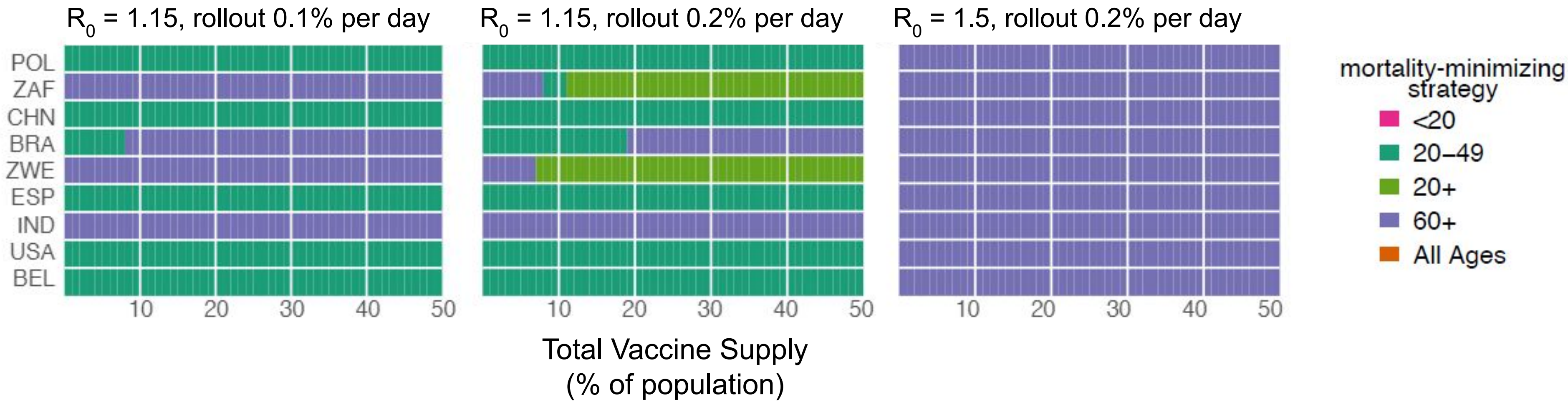
Transmission blocking

Do these results depend on the population structure?



Scenario:
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All-or-nothing, 90% ve
Transmission blocking

What if the vaccine only partially blocks transmission? (e.g. Pfizer/Moderna)

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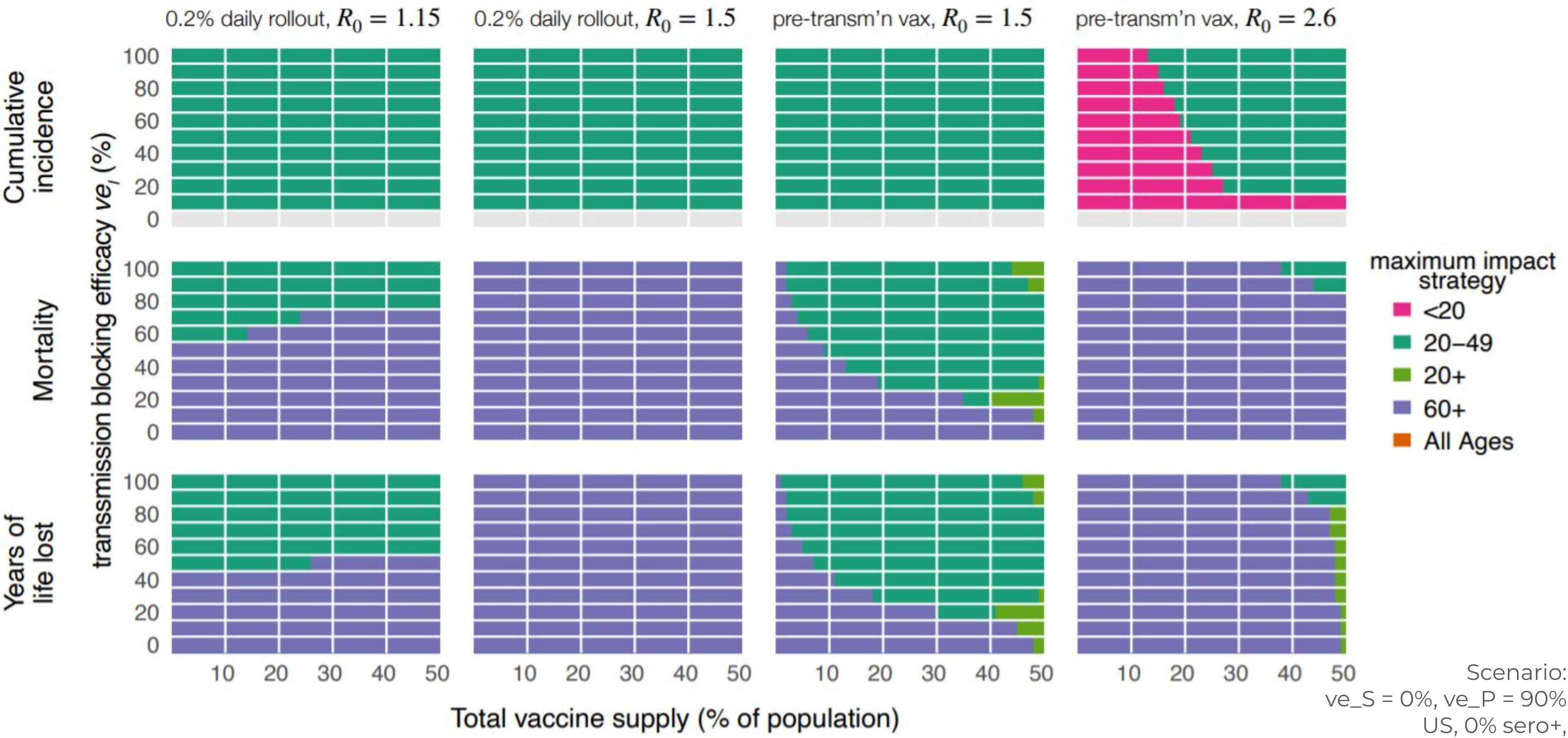


Scenario:
ve_S = 0%, ve_P = 90%
US, 0% sero+,
2% per day

General principles

Minimize mortality by directly protecting the most vulnerable
i.e. vaccinate adults 60+ first *unless:*

- low R, fast rollout, and excellent transmission blocking or
- low R, excellent transmission blocking, and ability to vaccinate before transmission or
- dramatic declines in efficacy among older adults [not shown]

Minimize cumulative incidence by prioritizing adults 20-49 first
(assuming the vaccine at least partially protects against infection or transmission)

Prioritization by serostatus (i.e. prioritizing IgG-) has the potential to extend the impact of limited supplies of vaccine [not shown]

Thinking about vaccine prioritization in 2022

- Prioritizing 60+ first is probably the way to go in most places, considering VE against delta and omicron variants and amount of ongoing transmission in many areas.

- A better understanding of the duration and strength of both infection- and vaccine-acquired immunity are vital.

- We need to evaluate and communicate the goal of vaccination, given low VE against infection and transmission.

Model-informed COVID-19 vaccine prioritization strategies by age and serostatus

Bubar, Reinholt, Kissler, Lipsitch, Cobey, Grad, Larremore
Science (2021)

SARS-CoV-2 Transmission and Impacts of Unvaccinated-Only Testing in Populations of Mixed Vaccination Status

Bubar*, Middleton*, Bjorkman, Parker, Larremore (preprint)

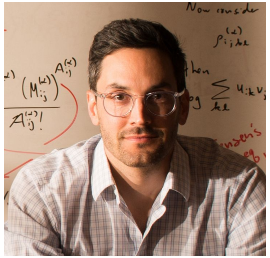
Kyle Reinholt
Colorado CSCI

Stephen Kissler
Harvard Inf. Dis.

Marc Lipsitch
Harvard Epi.

Sarah Cobey
Chicago EBIO & ID

Yonatan Grad
Harvard Inf. Dis.



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