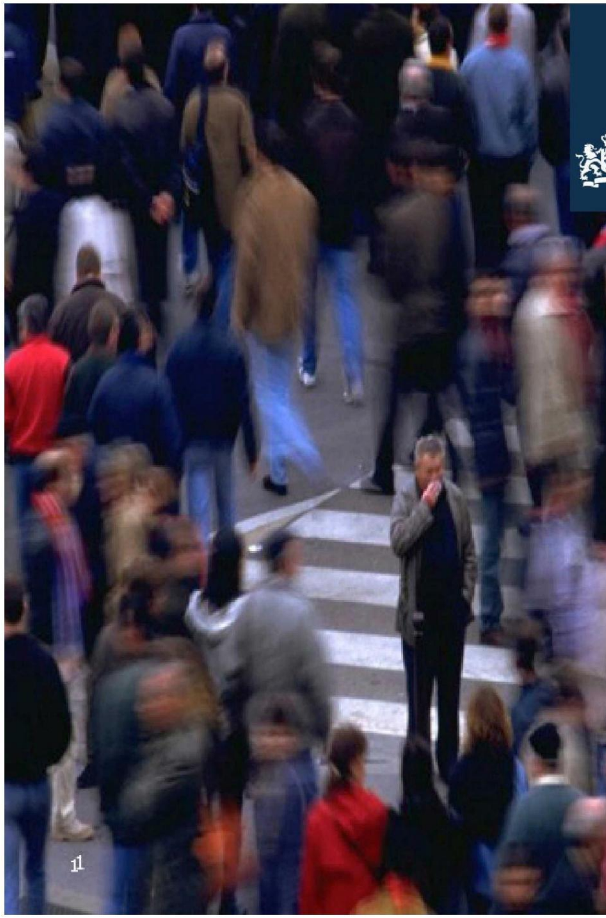

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Allocating COVID-19 vaccines

A data-based approach

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COVID-19 vaccines

- Many vaccines are in development
- 42 candidate vaccines in clinical evaluation
- Demand exceeds supply
- Clinical trials are ongoing
  - effectiveness against death, severe illness, illness, transmission, infection?
  - rate of vaccine-associated adverse events?
  - by sex, age, background?

Allocating scarce vaccines: a dilemma

- Objectives
  - minimize infections
  - minimize burden
  - open society as fast as possible
  - protect vulnerable groups
- Ethical context
  - equity
  - utility
- Setting
  - while maintaining control measures such as physical distancing, facemasks, etc
- Uncertainty
  - future pandemic
  - vaccine efficacy, effectiveness
  - adverse events
  - vaccine acceptance

Protecting the population: direct and indirect

rate of severe outcomes
=
probability of severe outcome given exposure to infection → direct protection
x
force of infection → indirect protection

Vaccination lowers the rate of severe outcomes by

- direct protection
  - directly benefits the vaccinee
  - measured in clinical trials
- indirect protection
  - benefits both vaccinated and unvaccinated individuals
  - if the vaccine reduces onward transmission by the vaccinee

Calculating the best allocation

Computational intensive approaches

1. specify objective
2. specify a model
3. (fit model to observations)
4. choose vaccine allocation
5. calculate outcome for this allocation with the model
6. repeat steps 4,5
7. determine the allocation with the best outcome

A data-based approach

1. specify objective
2. choose the relevant observations
3. calculate the optimal allocation for a broad class of models
4. choose a vaccine allocation
5. calculate outcome and compare with optimal allocation

Basic idea behind the data-based approach

- For any particular group
  - incidence reflects per capita risk of infection
  - force of infection reflects per capita number of at-risk contacts
  - together they determine the impact of blocking transmission in one person in that particular group
- This holds for any transmission model with a population partitioned by age, profession (and in some cases, location) and a contact matrix, as long as contacts are reciprocal

Technical specifications

- contact matrix for the contacts between and within groups can be written as a product of symmetric matrices
  - which is the case when contacts are reciprocal;
- contact matrix is nonnegative, irreducible, primitive
  - which is the case when introducing infection in one groups leads after a few generations to a positive number of infections in the other groups

PNAS

Optimizing infectious disease interventions during an emerging epidemic

[redacted] (10)(2e)

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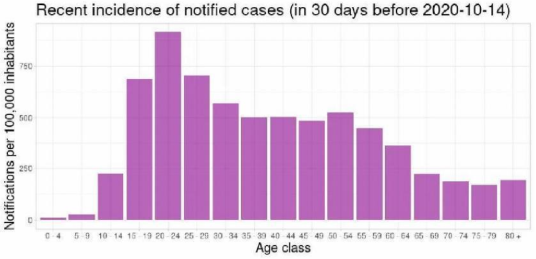
The emergence and global impact of the novel influenza A(H1N1)v which are unlikely to be available at the start of an emerging

Data: incidence of notified cases

- Notified cases by age for the Netherlands
- Testing policy: everyone with symptoms
- Similar pattern as in neighbouring countries



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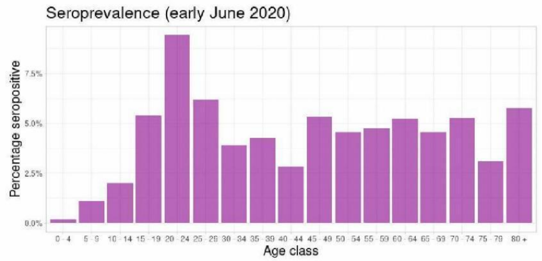
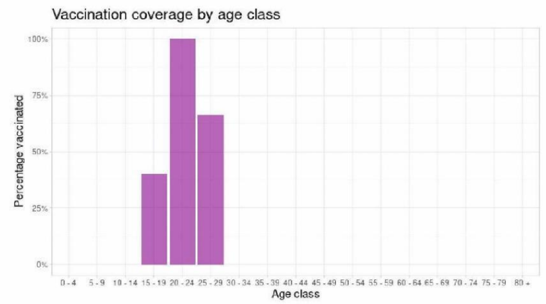
Data: seroprevalence

- Proportion seropositive by age
- Random sample of the Dutch population
- Similar pattern as in neighbouring countries



if the vaccine protects against transmission

- Allocation that results in the largest reduction of the reproduction number *R*
- When the amount of vaccines suffices to vaccinate about 10% of the population

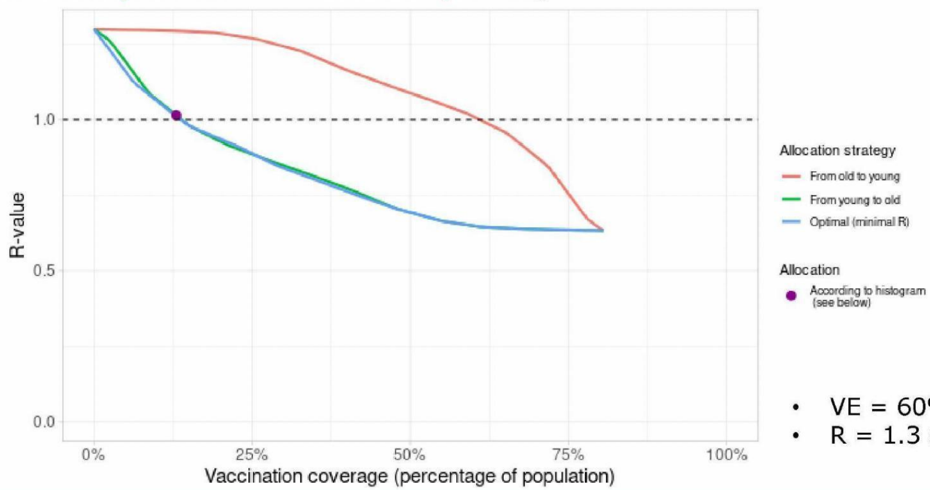


if the vaccine protects against transmission

- From old to young
- Young: 18 year olds
- Old: 90+ year olds

- From young to old
- Young: 18 year olds
- Old: 90+ year olds

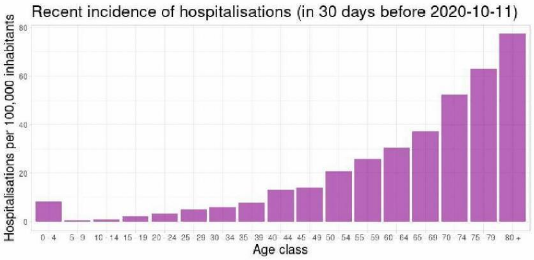
- optimal allocation that results in the largest reduction of the reproduction number *R*



- VE = 60%
- R = 1.3 at start

if the vaccine does not protect against transmission

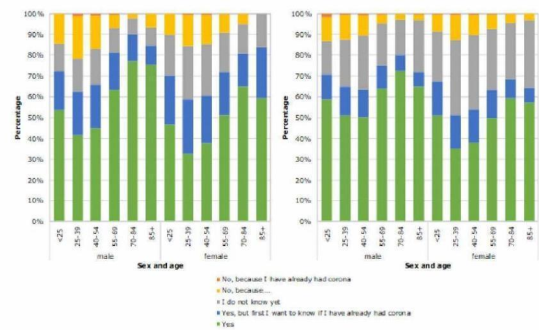
- Incidence of hospitalisations in the Netherlands
- Similar pattern as in neighbouring countries



Approach allows for including other data

- Age-specific
  - infectivity
  - susceptibility
  - vaccine efficacy
  - vaccine acceptance
- Information on past SARS-CoV-2 infection
- Different partitions of the population
  - age
  - profession
  - in some cases, location

"Would you like to be vaccinated?"
Answers for late May (left) and early July (right)



Conclusions so far

- If vaccine is effective against transmission
  - allocating in order of increasing age from 18 yr towards elderly is nearly optimal in reducing transmission
  - this provides indirect protection of the population
- If vaccine is not effective against transmission
  - allocating in order of decreasing age from elderly towards 18 yr is best in reducing hospitalisations
  - this provides direct protection to the vaccinees
- Since we don't know how effective the vaccine protects against transmission, it is too early to give the best ranking who should be vaccinated first

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