Vaccine Impact

The impact of a vaccination program is defined as the proportion of events (e.g., cases, hospitalisations, deaths) prevented in a population with vaccination compared to a population without vaccination. Using modelling we can assess a vaccination program's impact by comparing simulated populations with and without vaccination under the same conditions. In this section, we report the impact of several possible vaccination programs in The Netherlands with respect to new infections, new cases, hospital admissions, and intensive care admissions. The vaccination scenarios assessed are:

1) Old to young: vaccination begins with 50-59 year olds and then progresses through 10-year age bands in decreasing order (50-59, 40-49, etc.)
2) Young to old: vaccination begins in 18-19 year olds and then progress through 10-year age bands in increasing order (18-19, 20-29, 30-39, etc.)
3) Alternative: vaccination begins in 18-30 years olds followed by 50-59 year olds and then progresses to 40-49 year olds and then 30-39 year olds.
4) No vaccination: there is no vaccination at all

Summary

Regardless of the vaccination scenario, implementing a COVID-19 vaccination program results in fewer cumulative new infections, new cases, hospital admissions, and IC admissions compared to no vaccination (Table 1). Overall, there was very little difference between the different vaccination programs (Figure 1), but the old to young vaccination program resulted in the fewest outcomes. Using IC admissions as the criteria by which to relax measures resulted in fewer infections, cases, hospital admissions, and IC admissions compared with using new daily cases as the criteria.

Methods

We used a compartmental susceptible-exposed-infectious-recovered model extended to include additional states for hospitalisations, IC, and deaths. Cases are calculated as a proportion of infectious persons. We fit the model to hospital admission data from NICE to obtain an estimate of $R_0 = 3.03$. We account for differences in susceptibility and infectiousness by age group by multiplying the relative susceptibility/infectiousness by the contact matrix. The model begins on 1 February 2021 and simulates forward in time until 30 September 2021. Initial conditions were set based on data from 1 February 2021: hospital admissions from NICE, new positive tests (cases) data from OSIRIS, and IC admissions from Dashboard Coronavirus (https://coronadashboard.rijksoverheid.nl/). The number of exposed individuals was assumed to be the number of cases on 1 February 2021 scaled by the estimated probability of being reported (0.428) and multiplied by the latent period. The number of infectious persons was assumed to be within the range estimated for 1 February 2021 from Dashboard Coronavirus so that the number of hospital admissions matched those on 1 February 2021. All individuals vaccinated before 1 February 2021 are assumed to be vaccinated on 1 February. We only include vaccination with Pfizer and AstraZeneca. Vaccination with the Pfizer vaccine occurs prior to AstraZeneca vaccination in healthcare workers and the very elderly according to the vaccine distribution schedule. AstraZeneca vaccination in healthy individuals starts on 7 June

2021. We assume 800,000 vaccine doses are administered per week, which are allocated evenly across the 7 days within the week. Only the first dose of the AstraZeneca vaccine is allocated because the timing for the second dose (12 weeks after the first dose) falls outside the time window of this simulation. We vary the order of AstraZeneca vaccine receipt in healthy adults depending on the vaccination scenario. At the beginning of the simulation, the lockdown (April 2020) contact matrix is assumed. Once new daily cases fall below 14.3 per 100,000 non pharmaceutical interventions are relaxed and the contact matrix from September 2020 is assumed. If new daily cases rise above 35.7 per 100,000, strict measures (April 2020 contact matrix) are reimposed. To determine if there was a difference between using new cases as the criteria by which to relax measures, we also used IC admissions as a threshold. Once daily IC admissions fell below 10 measures were relaxed. If IC admissions rose above 20 per day, stricter measures were reimposed.

Results

Regardless of the vaccination scenario, implementing a COVID-19 vaccination program results in fewer cumulative new infections, new cases, hospital admissions, and IC admissions compared to no vaccination (Table 1). Overall, there was very little difference between the different vaccination programs (Figure 1). The old to young vaccination program resulted in the fewest outcomes (Table 1) with 87.5% fewer cumulative infections, 86.5% fewer cumulative cases, 86.0% fewer hospital admissions, and 85.2% fewer IC admissions compared to no vaccination (Table 2).

To determine if there was a difference between using new cases or IC admissions as the criteria by which to relax measures, we also used IC admissions as a threshold. Once daily IC admissions fell below 10 measures were relaxed. If IC admissions rose above 20 per day, stricter measures were reimposed. The old to young vaccination program resulted in the fewest cumulative infections, cases, hospital admissions, and IC admissions (Table 3) with 87.2% fewer cumulative infections, 89.5% fewer cumulative cases, 88.0% fewer hospital admissions, and 87.2% fewer IC admissions compared to no vaccination (Table 4). The young to old and alternative vaccination strategies resulted in only slightly higher outcomes compared to old to young.

Using IC admissions as the criteria by which to relax measures resulted in fewer infections, cases, hospital admissions, and IC admissions compared with using new daily cases as the criteria. This may be due to the fact that the model incorporates age-related susceptibility and infectiousness and older people have the highest susceptibility, infectiousness, and probability of going to the IC. Therefore, by minimising IC admissions before relaxing restrictions and vaccinating the elderly (which helps prevent IC admissions from increasing once measures are relaxed) the contribution of the elderly to the epidemic is greatly reduced. Additionally, it may take longer for IC admissions to go below their threshold because of the length of time from infection to IC admission. Thus, measures are not relaxed as quickly as when using cases as the criteria.

Tables and Figures

Table 1. Cumulative totals of each outcome under the four vaccination scenarios: old to young, young to old, alternative, and no vaccination. New daily cases are used as the criteria to relax/tighten restrictions.

Scenario\Outcome	New Infections	New Cases	Hospital Admissions	IC Admissions
Old to young	**622,914**	**310,416**	**13,925**	**5,254**
Young to old	628,315	314,470	13,965	5,262
Alternative	628,072	314,274	13,970	5,265
No Vaccination	4,985,401	2,300,840	99,715	35,640

Table 2. Percent difference of each outcome under the four vaccination scenarios: old to young, young to old, alternative, and no vaccination. No vaccination is used as the reference. New daily cases are used as the criteria to relax/tighten restrictions.

Scenario\Outcome	New Infections	New Cases	Hospital Admissions	IC Admissions
Old to young	-87.5%	-86.5%	-86.0%	-85.2%
Young to old	-87.4%	-86.3%	-86.0%	-85.2%
Alternative	-87.4%	-86.3%	-86.0%	-85.2%
No Vaccination	reference	reference	reference	reference

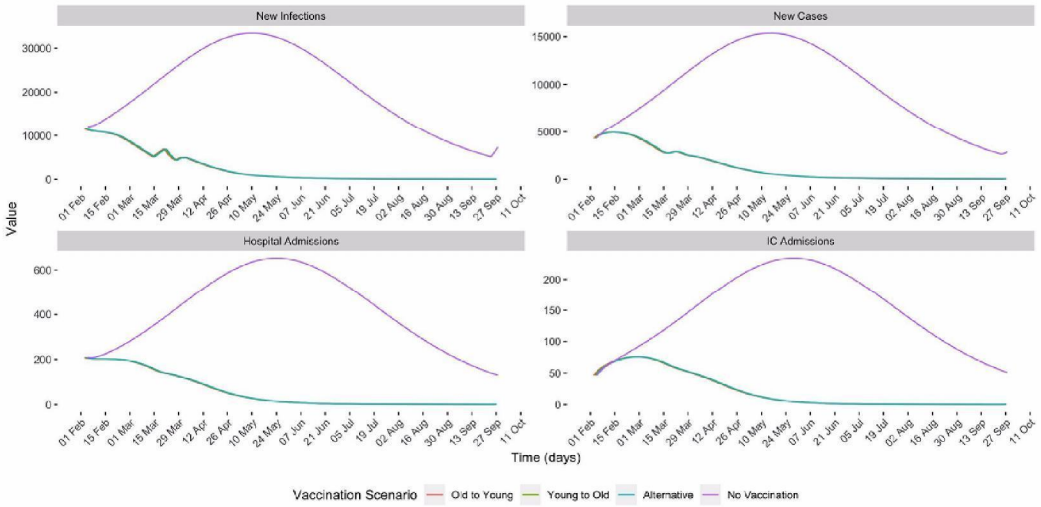

Figure 1. 7-day rolling average of new infections, new cases, hospital admissions, and IC admissions under different AstraZeneca vaccine allocation scenarios: 1) old to young, 2) young to old, 3) alternative, 4) no vaccination. The non-pharmaceutical interventions are relaxed once daily new cases fall below 14.3 per 100,000. Note: lines for the vaccine strategies have been jittered for increased visibility.

Table 3. Cumulative totals of each outcome under the four vaccination scenarios: old to young, young to old, alternative, and no vaccination. Daily IC admissions are used as the criteria to relax/tighten restrictions.

Scenario\Outcome	New Infections	New Cases	Hospital Admissions	IC Admissions
Old to young	**489,901**	**241,404**	**11,928**	**4,575**
Young to old	491,248	242,411	11,938	4,577
Alternative	491,187	242,363	11,939	4,578
No Vaccination	4,967,494	2,297,836	99,697	35,639

Table 4. Percent difference of each outcome under the four vaccination scenarios: old to young, young to old, alternative, and no vaccination. No vaccination is used as the reference. Daily IC admissions are used as the criteria to relax/tighten restrictions.

Scenario\Outcome	New Infections	New Cases	Hospital Admissions	IC Admissions
Old to young	-90.1%	-89.5%	-88.0%	-87.2%
Young to old	-90.1%	-89.5%	-88.0%	-87.2%
Alternative	-90.1%	-89.5%	-88.0%	-87.2%
No Vaccination	reference	reference	reference	reference

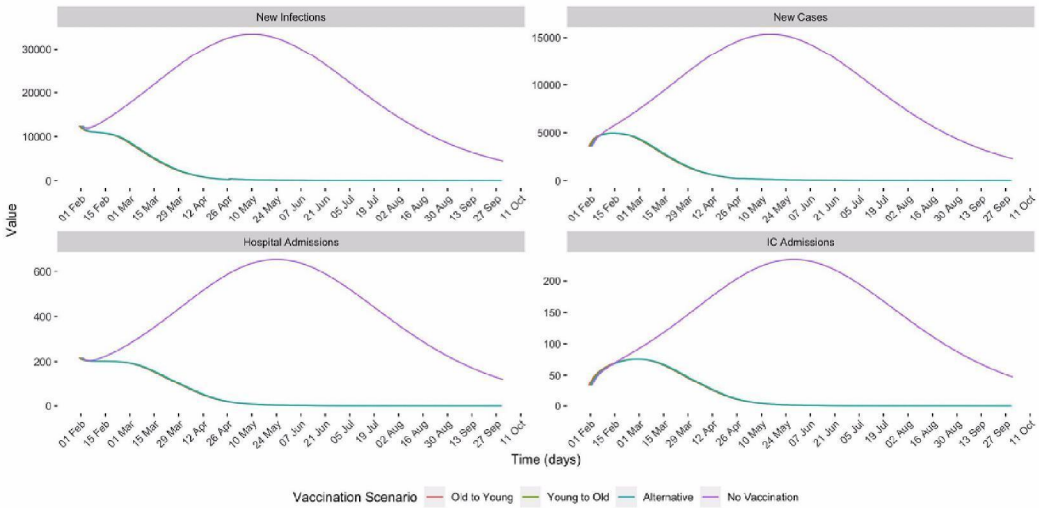

Figure 2. 7-day rolling average of new infections, new cases, hospital admissions, and IC admissions under different AstraZeneca vaccine allocation scenarios: 1) old to young, 2) young to old, 3) alternative, 4) no vaccination. The non-pharmaceutical interventions are relaxed once daily IC admissions fall below 10 per day. Note: lines for the vaccine strategies have been jittered for increased visibility.