Illustrative model-based analysis of vaccination and release strategies (Scotland)

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Policy relevance

- Model outputs are scenarios NOT predictions.
- Under the most optimistic assumptions about vaccine efficacy and coverage, at 200K vaccinations per week it will be 5-6 months before the population immunity threshold is reached in Scotland.
- Under more pessimistic but plausible assumptions about vaccine efficacy and coverage, the population immunity threshold will never be reached.
- There are multiple options for a phased removal of restrictions as vaccination is rolled out.
- Under all scenarios modelled here, full release of the entire population immediately after vaccination of the highest priority 33% of the population (or fewer) results in a major epidemic with significant number of cases (=high attack rate) in the most vulnerable groups,
- Most cases in the vulnerable group are in individuals who have not been vaccinated or previously exposed. Incidence declines over the first vaccination round, with attack rate approximately 2.5% in baseline scenario.
- Delaying full release until 66% of more of the population has been vaccinated results in much lower attack rates in all groups.
- Releasing the vaccinated population at the 33% point results in much lower attack rates.
- Partially releasing the entire population at the 33% point can result in lower attack rates, but this may require a very limited lifting of current restrictions.
- In the short term (12 months), the main challenges to tackle in order to reach the population immunity threshold (if it is possible) are: slow vaccine roll-out; low coverage; low transmission blocking efficacy.

Methods summary

SIRV compartment model with three equal-sized population sub-groups and sub-group specific transmission rates.

Constant fraction vaccinated per day (target coverage 90%).

Four strategies for release from lockdown: A) release each subgroup once the whole group has been vaccinated; B) release the whole population once the first group has been vaccinated; C) release the whole population once the first two groups have been vaccinated; D) release the whole population once all groups have been vaccinated.

Starting conditions: 0.79% currently infected and 7.3% have natural immunity. Equal across subgroups.

Outputs are: 1) overall attack rate over one year from start of vaccination programme; 2) attack rates by subgroup; 3) attack rate among fully susceptible individuals in group i (high priority).

Compare outputs for different values of: current R value; post-release R value (partial release); restricted mixing between subgroups; decay of natural and/or vaccine-induced immunity; transmission blocking efficacy; coverage.

Results Summary

Baseline population immunity threshold = 65%. New variant increases this to 77% (upper limit 79%).

Baseline scenario gives one-year attack rate in all groups below 4%, except for strategy B (full release after 33% vaccination) which has an overall attack rate of 50%.

In baseline strategies A, C and D almost all cases occur in the first 90-day vaccination round. For strategy B cases peak in the second vaccination round.

If pre-lockdown R is higher (1.4 cf. 1.0) then attack rates increase to >10% in all groups (lowest in group i) and all epidemic extend into the second vaccination round.

For strategy B partial rather than full lifting of restrictions limits the epidemic. 50% relaxation is too much, 25% relaxation brings the attack rates in line with other strategies.

Reducing transmission between subgroups (by 50%) also reduces the attack rate, especially for group i.

Waning vaccine-induced immunity (mean duration = 6 months) compromises all strategies, though with a delay. Waning natural immunity has much less impact.

Poor transmission blocking efficacy (75% cf. 99%) increases attack rates, but especially for strategy A (overall attack rate = 40%) making this strategy untenable.

Low vaccination coverage severely compromises all strategies as the population immunity threshold is not attained. The full consequence of this is not seen until beyond the one-year window of these simulations.

Remarks

This analysis provides insights in to the complex dynamics of a combination of virus spread, the impact of NPIs and vaccine roll out. We use the model to explore different scenarios that shed light on these dynamics over a one-year period. They are not predictions.

We do not model time delays to full protection nor to second dose. This will shift the curves to the right on the time axis by a minimum of two weeks.

In future work we will weight attack rates by the risk of hospitalisation and death. For immediate purposes we focus on the attack rate in group i individuals who have not been vaccinated or previously infected – this is the group that are expected to make the largest contribution to hospitalisations and deaths.

We have calculated one-year attack rate as a useful metric, not least because annual vaccination may be possible/necessary. We note that different strategies result in different distributions of cases over this period.