Relaxation of NPI as vaccination proceeds

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Executive Summary.

1) The combined action of current restrictions and mass vaccination leads to faster than exponential decay of infection and other important public health measures (hospital admissions, hospital occupancy and deaths). Under these controls, hospital occupancy is expected to fall below 10,000 in April, and fall below 1,000 in late May or early June.
2) Relaxation of NPIs is however vital to many areas of society, although it leads to an increase in R_t. Here we consider three different approaches to understand the interplay between vaccine roll-out and relaxation of control measures, and simulate for the entire UK:
   a. As requested by SPI-M; a step change in NPIs in February, followed by a gradual decline over 3, 6 or 9 months once hospital occupancy falls below 10,000 (in April).
   These simulations show that rapid release of controls leads to a large wave of hospital admissions; while slow release is able to maintain some degree of control. Faster roll-out of vaccination substantially reduces subsequent peaks.
   b. Five different sets of NPI restrictions coming into force in the middle of February, March, April or June.
   Relaxation of restrictions that if enacted in February would generate a substantial third wave have a low or moderate effect if delayed until April. Complete removal of all restrictions, even as late as June, leads to a very rapidly rising number of infections.
   c. Optimal relaxation of controls subject to keeping hospital occupancy below 10,000 patients.
   This shows that gradual lifting of restrictions can maintain hospital occupancy below 10,000; but this requires some measures to persist until 2022. Under this form of gradual relaxation, we could reach September 2020 like controls by the Summer. This highlights the potential of scenario modelling if a suitable objective function can be defined.
   d. Relaxation of controls once priority groups 1-4 have received two doses of vaccine, and groups 5-9 have received at least one dose.
   Here we consider variability in the vaccine's ability to block infection, but conclude that even with high levels of infection blocking immediate release of all controls generates extremely large subsequent waves of infection.
3) The generic conclusion is that control measures need to be relaxed slowly – and that a gradual relaxation is better than a delay followed by a more abrupt change in policy. Not only is this better from a public-health perspective but it allows more rapid re-implementation of controls if infection levels begin to increase too quickly.
4) The work assumes that vaccine roll-out strictly achieves the JCVI priority ordering. In practise there will be blurring of the priority groups due to the difficulty of reaching many elderly individuals – this will lessen the impact of vaccination.
5) We assume a maximum delivery of 2.5M doses per week (4M per week is considered in Figure 2); see Appendix. We also assume 2 doses of the vaccine prevents 88% of symptomatic illness (and hence 88% of hospital admissions and deaths) and 60% of infection (and hence reduces onward transmission by 60%). This latter assumption has extremely low confidence due to the available data.
6) Faster vaccine roll-out will shorten many of the model timescales, while higher efficacy or higher uptakes will further reduce cases and hospital admissions.
7) Simulations are performed regionally, but only UK aggregate results are shown.

a) SPI-M Commission

This is the requested commission. The model is simulated forwards under current restrictions until mid-February, at this point R_t is set at 0.8 (higher NPIs) in all regions until Hospital Occupancy falls below 10,000. The strength of NPI restrictions then decreases linearly over the next 3 (red), 6 (green) or 9 (blue) months, to reach 25% of the initial value. This decreasing level of control would lead to an increase in R_t, but this is to some extent mitigated by the build-up of immunity due to vaccination and natural infection.

Figure 1 upper panel illustrate this, plotting the average level of NPIs relative to current restrictions. Existing heterogeneities in effective control between regions are not shown as we plot a UK average. NPIs at around 60% of their current (January 2021) value are comparable to restrictions in September 2020.

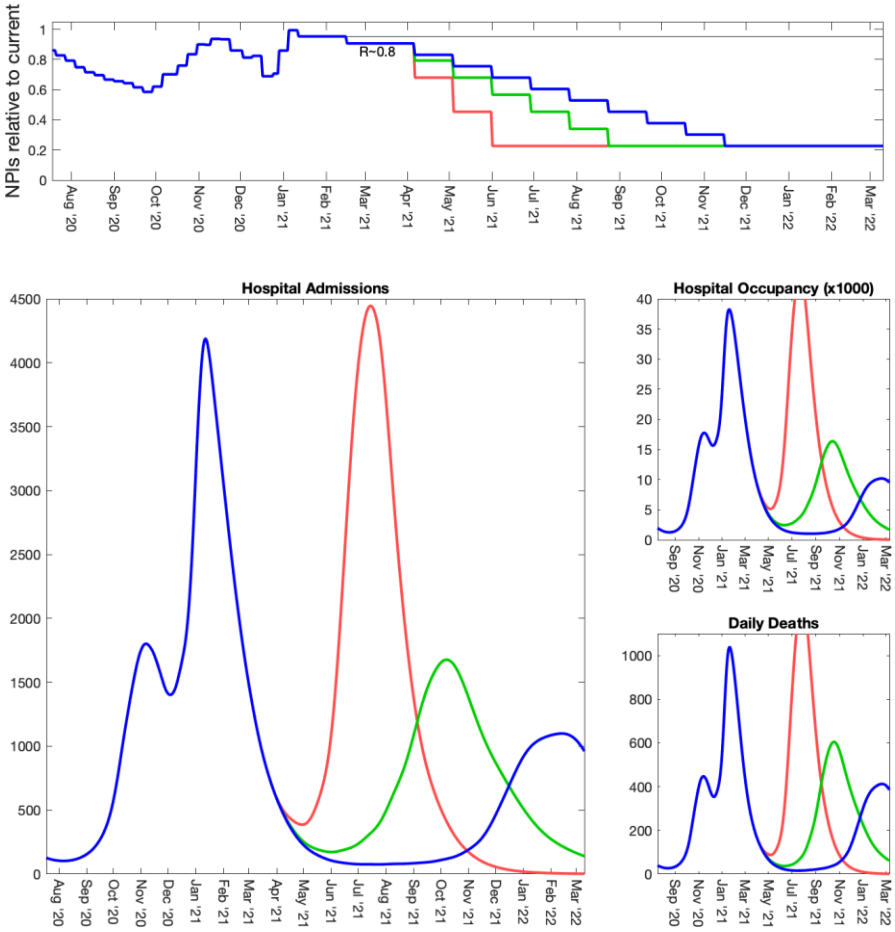


Figure 1: Mean dynamics for three NPI profiles, showing hospital admissions, occupancy & deaths, summed across all regions of the UK. Assumes vaccine doses are approximately 2.5M per week.

This generates three resultant epidemics (Figure 1, for clarity we omit credible intervals and focus on mean values averaged over posterior parameter distributions). We focus on hospital admissions as the key quantity of interest, but also show hospital occupancy and daily deaths in sub-figures.

Given R_t is set to 0.8 in all regions in mid-February , then infection declines until April when hospital occupancy reduces below 10,000 for the first time this year. The switch to a declining

level of NPI controls precipitates a subsequent epidemic wave, although this is smaller and later if controls are relaxed over longer time scales. Rapid releasing of controls over a 3-month time frame (red) generates a large third wave of infection with more hospital admissions and deaths than seen during January 2021. Relaxing controls over 9-months (blue) produces a sustained trough until late 2021.

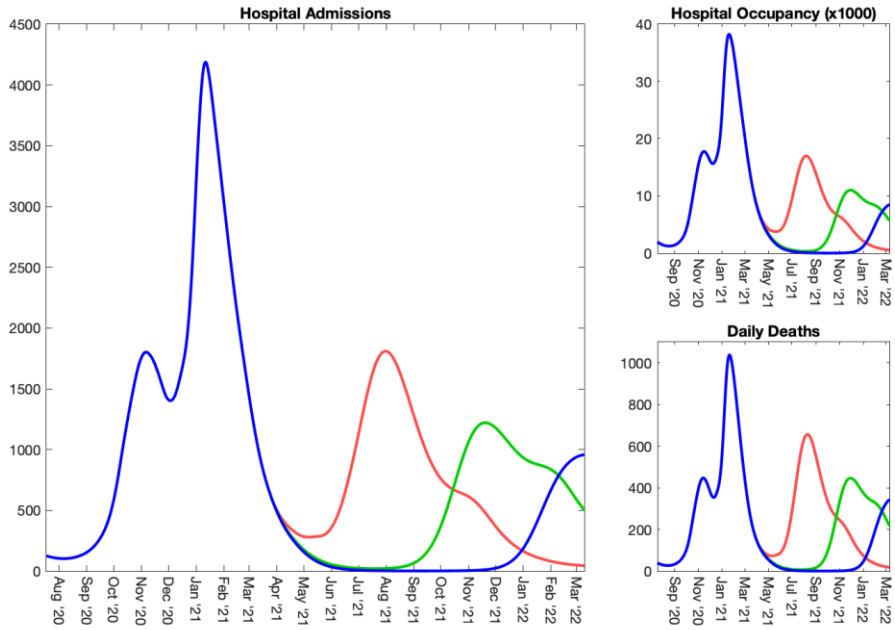


Figure 2: Mean dynamics for three NPI profiles, showing hospital admissions, occupancy & deaths, summed across all regions of the UK. Assumes vaccine doses are approximately 4M per week from March onwards.

Far lower levels of subsequent epidemic waves can be achieved if we manage to realise 4 million doses of vaccine administered per week.

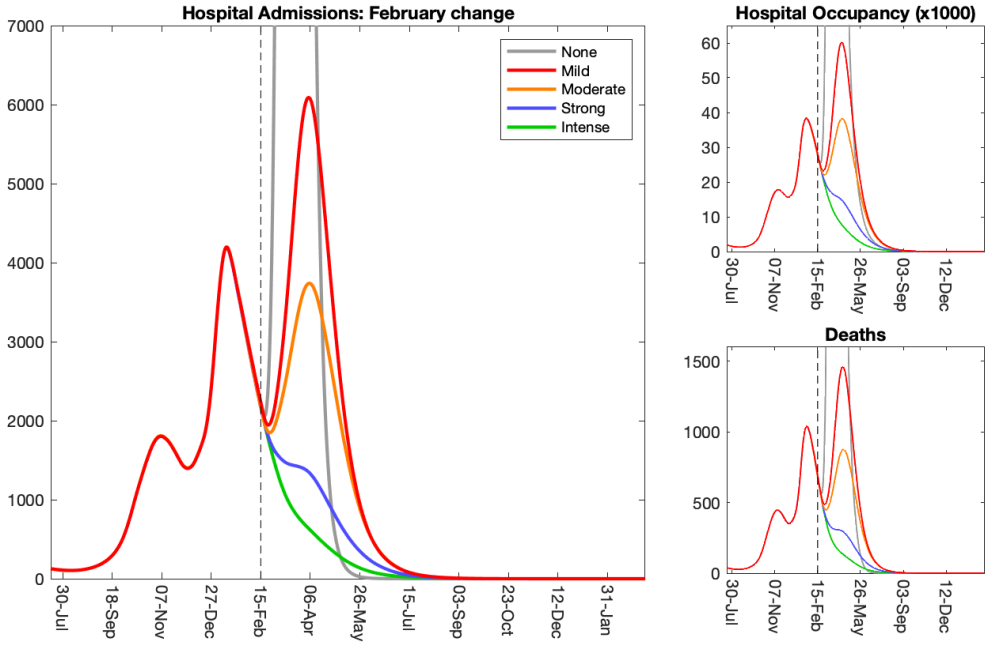
Conclusions.

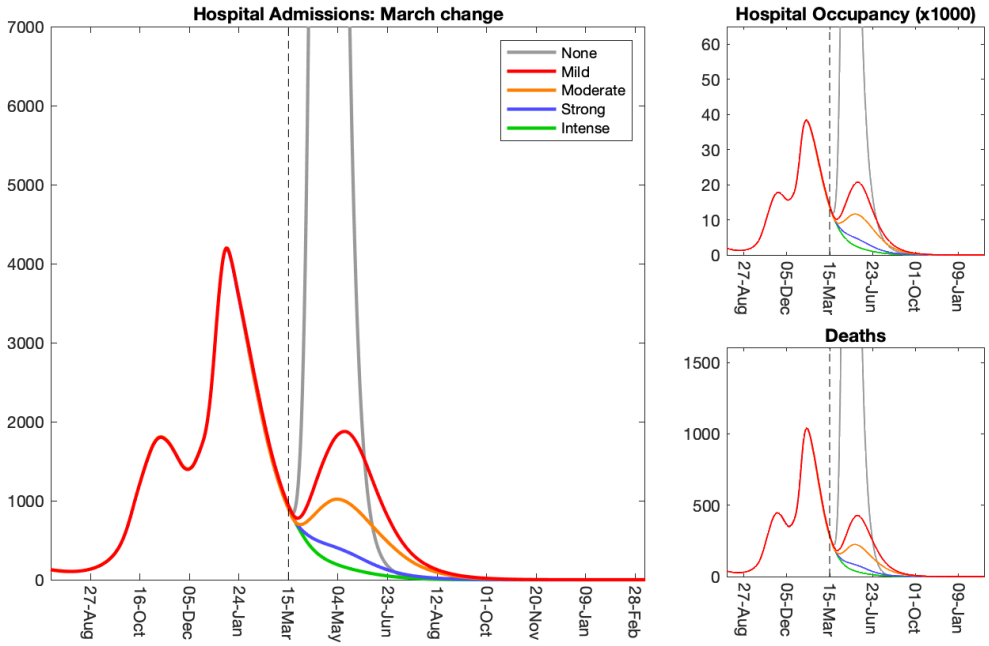
Maintaining the current level of controls (or R_t=0.8) we can drive hospital occupancy below 10,000 patients by late March or early April. Following this, only a slow relaxation of NPIs, taking 9 months (until January 2022) to reach 25% of their value, can maintain a low number of expected hospital admissions and keep subsequent waves of infection under tight control.

b) Partial Relaxation at Different Times

We define five different levels of NPI restrictions: Intense (green, which generates $R_t \approx 0.8$ in mid-February); Strong (blue, which generates $R_t \approx 0.9$ in mid-February); Moderate (orange, which generates $R_t \approx 1.1$ in mid-February); Mild (red, which generates $R_t \approx 1.2$ in mid-February); and none (grey, which generates $R_t \approx 3.0$ in mid-February). When implementing these NPI restrictions at later dates, the associated value of R_t is decreased by the build-up of immunity in the population.

We consider a change from the current restrictions to these new NPIs in the middle of February, March, April, May and June, and show hospital admissions (main panel), hospital occupancy and deaths (subpanels).





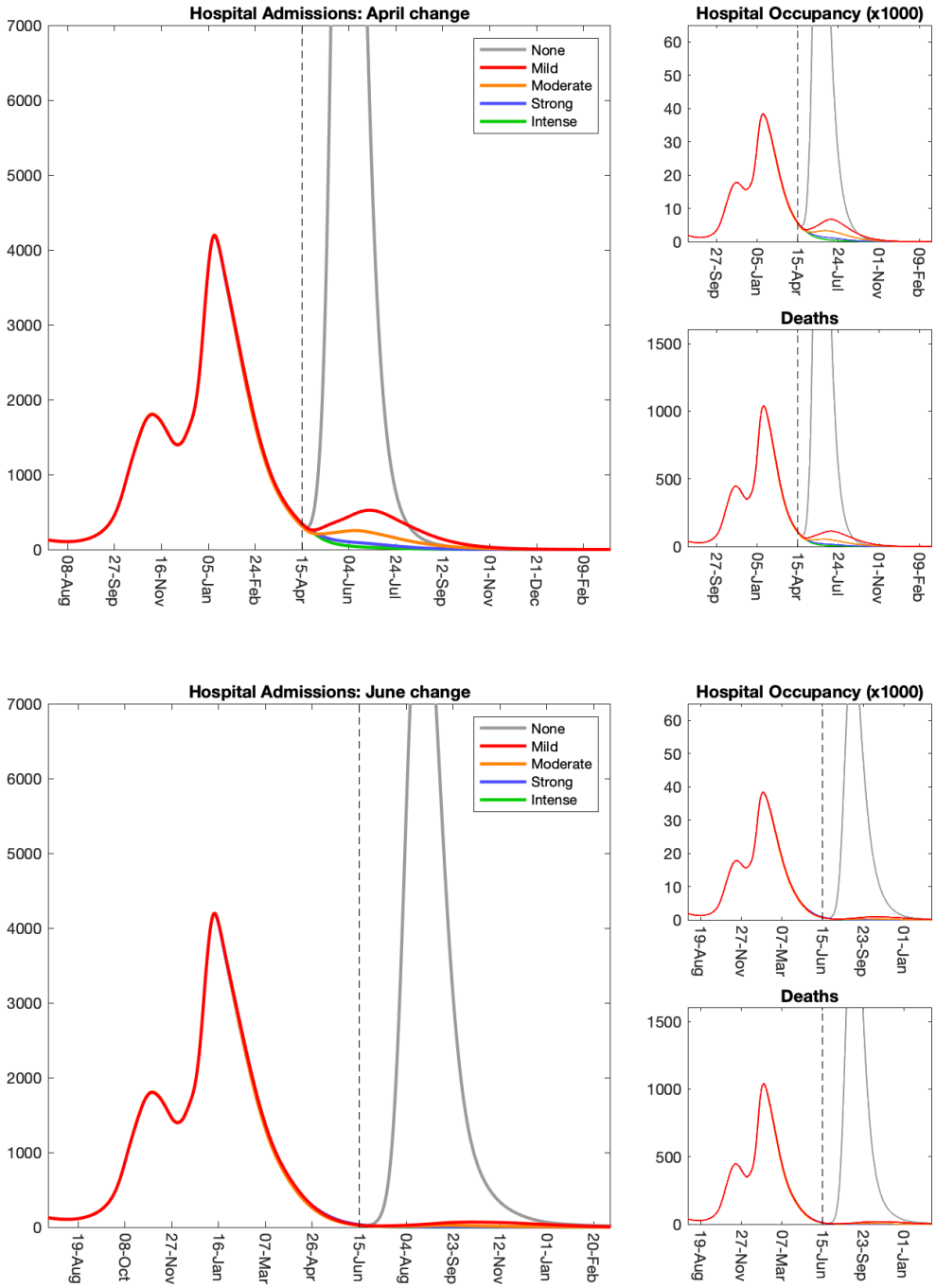


Figure 3: Implications of relaxation of NPIs at different time points, allowing more vaccine-derived immunity to accrue. Colours correspond to different levels of control which are matched to specific values of R_t in February (Intense R_t=0.8; Strong R_t=0.9; Moderate R_t=1.1; Mild R_t=1.2; None R_t~3). A switch to these controls is made in the middle of February, March, April and June.

Later implementation of this change in NPIs leads to far smaller subsequent outbreaks, owing to the additional build-up of immunity in the population (primarily through vaccination). However, complete relaxation of all NPI controls (shown in grey) still leads to a rapidly-growing and overwhelming epidemic even when it is not implemented until June. The complete cessation of controls, allows infection to grow at its maximum possible rate – although this is

reduced from March 2020 by the build-up of population immunity, but increased by the faster transmission of the new variant. In February, complete relaxation leads to R_t~3.0, and by June the increase in immunity due to vaccination is still insufficient to overcome this effect. Peak daily deaths for the complete relaxation scenarios are: 12,000 for a February release, 7,400 for a March release, 4,100 for an April release, and 2,500 for a June release.

Conclusions

Relaxation to a set of controls that are predicted to cause major waves of hospital admission if they occur in February (mild & moderate) have limited impact if they are delayed to April; but a complete and abrupt cessation of all NPIs is still problematic any time in 2021.

c) Optimal Relaxation

An alternative approach to this problem is to fix an acceptable threshold and allow NPIs to relax as quickly as possible while maintaining dynamic quantities below this threshold. Here we insist that hospital occupancy must fall below 10,000 in the same time as if the current restrictions were maintained, and after this point occupancy (across the entire UK) can never exceed 10,000 – a more refined strategy would be to set this regionally. This optimisation process is over a large-dimensional space, and therefore we only perform this calculation for a small number of random samples from the full parameter distribution.

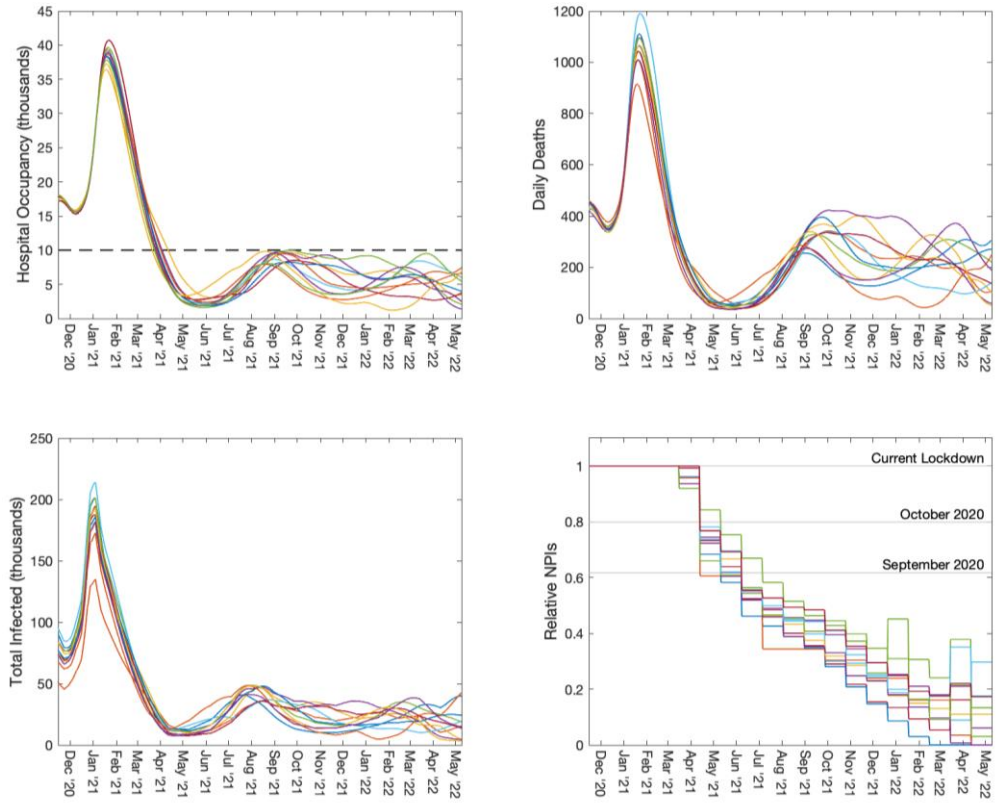


Figure 4: Optimised simulations that relax controls as quickly as possible, while first reducing hospital occupancy quickly and then keeping occupancy less than 10,000. Each line shows a single optimisation of one posterior parameter set from the MCMC inference.

We expect hospital occupancy to fall below 10,000 by mid-April, and for a slight relaxation in NPIs to be allowable just before this time. The 'optimal' solution that maintains occupancy below 10,000 but minimises restrictions then has NPIs gradually falling until some point in 2022 depending on parameters.

We stress that with this solution, mortality remains relatively high. However, predictions over such long time-scales are critically dependent on a number of features including: seasonality; vaccine uptake; transmission blocking capacity of the vaccine; and the impact of the vaccine on severe disease.

<u>Conclusions</u>

Given an objective function (such as keeping hospital occupancy below 10,000) it is possible to relax the restrictions as quickly as possible. The objective function needs very careful policy input, and the long-term behaviour is at best a guide to the approximate time-scale for the lifting of different measures.

d) Relaxation after vaccinating priority groups 1-9

Here we consider the lifting of restrictions once priority groups 1-4 have received two doses of vaccine, and groups 5-9 have received at least one dose; this occurs in mid-May based on current deployment estimates, but we show all curves relative to this time point.

We consider three sets of assumptions, which taken in combination give eight scenarios:

i) High (70%, blue) or Low (30%, red) infection blocking, which has implications for the level of onward transmission.
ii) Immediate (solid line) or gradual over a 3-month period (dashed lines) relaxation of controls.
iii) Return to pre-covid mixing (figure 5) or assuming that the public retains some degree of caution such that 25% of NPI remain (figure 6).

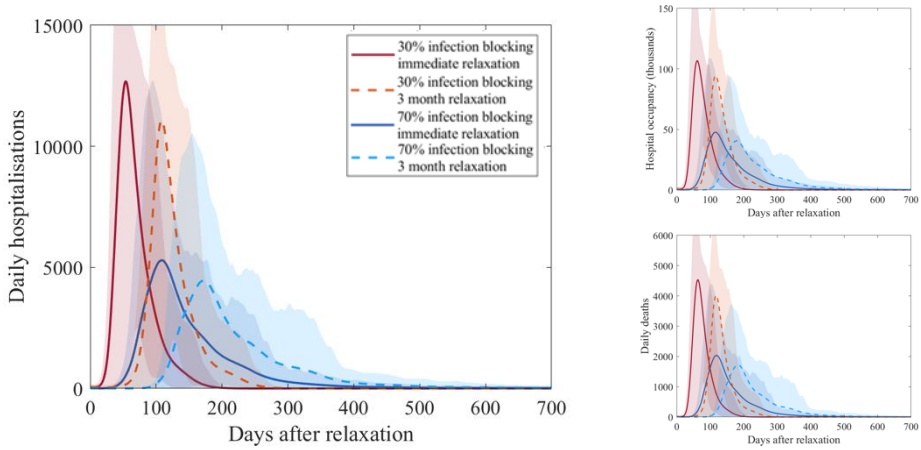


Figure 5: complete relaxation after completion of vaccinating JCVI priority groups 1-9 (2 doses in groups 1-4, 1 dose in groups 5-9); solid lines refer to immediate relaxation, dashed lines are for a slow release over 3 months.

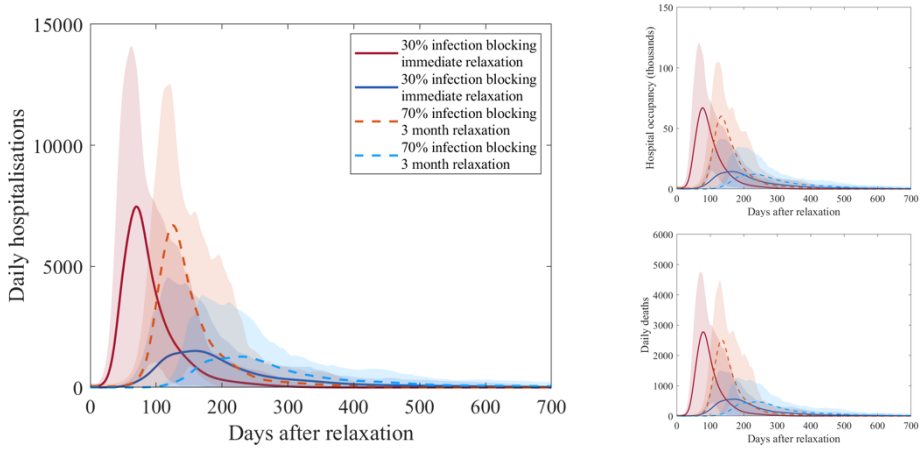


Figure 6: partial relaxation to 25% of current levels after completion of vaccinating JCVI priority groups 1-9 (2 doses in groups 1-4, 1 dose in groups 5-9); solid lines refer to immediate relaxation, dashed lines are for a slow release over 3 months.

These results show that all three sets of assumptions impact the likely future dynamics. Infection blocking efficacy (blue compared to red) has by far the largest impact, as this controls the underlying epidemiological transmission; unfortunately, this is also one of the most uncertain parameters. A gradual decline compared to an abrupt change (dashed compared to solid) leads to a slight reduction in any subsequent peaks and delays the time to these peaks.

Finally, assuming that the general population retains some level of increased vigilance (Figure 6 compared to Figure 5) leads to a general reduction in all measures, and is most pronounced when infection blocking efficacy is also high.

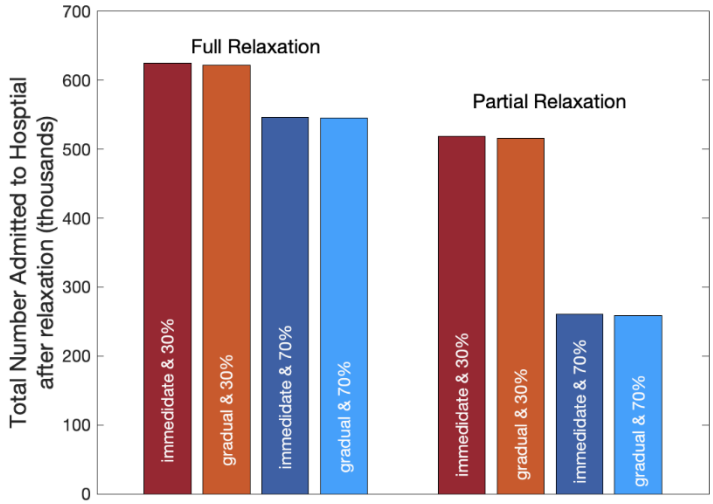


Figure 7: The total number of patients admitted to hospital with COVID from the start of relaxation until the end of 2022. Colours represent the two sets of assumptions about infection blocking and immediate or gradual relaxation, while the two sets of bars compare full and partial relaxation.

Conclusions

Once all individuals in priority groups 1-9 have received at least one dose of vaccine, complete relaxation of controls leads to extremely high levels of infection – especially if all controls are released immediately. Less severe outcomes are predicted with a gradual release to a scenario with some moderate level of control.

Appendix: Vaccination Assumptions.

We have based our assumptions on plausible assumptions about vaccination, in terms of protection, uptake and delivery.

Protection.
The vaccine is assumed to generate protection against infection – partially preventing both asymptomatic and symptomatic infection. We assume an efficacy against infection of 48% and 60% three weeks after the first and second dose respectively. This prevention of infection, naturally leads to a reduction in onward transmission.

For those that have been vaccinated but do get infected, the vaccine also protects against symptomatic disease. The combination of protection against infection and subsequent protection against disease leads to the commonly quoted vaccine efficacy values: we assume 70% and 88% three weeks after the first and second dose respectively. These values are a weighted averaged between the efficacies published by AstraZeneca and Pfizer.

We do not consider the potential further action of the vaccine on reducing hospital admission or death if the individual develops symptomatic disease – current data are consistent with there being no additional protection, but the confidence intervals are wide.

Uptake.
Throughout we have assumed 85% uptake across all age groups. This is potentially an under-estimate for the elderly and vulnerable, but an over-estimate for younger individuals. These is little or no data to underpin our assumption.

Delivery.
We have mimicked the known age-group and regional delivery of vaccine to date, but there is considerable uncertainty going forwards.

We assume that vaccine is delivered according to the JCVI priority ordering (although it is clear that in many regions this ordering is not strictly achievable) and that the second dose is given at 12 weeks after the first, from March onwards we have assumed 2.5 million doses a week (unless otherwise stated).