"Unlocking" Roadmap Scenarios for England

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We explored 4 scenarios for England as set out by the Cabinet Office, where non-pharmaceutical interventions (NPIs) were lifted at different speeds and extents over the next 3–6 months. The increase in transmissibility from the successive easing of restrictions was translated as set out in Table 1. The dates of easing and vaccine roll out schedule (Table 3) were pre-specified. Current levels of transmissibility are based on our most recent estimates for England at R_{eff} (including immunity) = 0.8 (translating to $R_{excl\_immunity}$=1.1 with an estimated 32% of the population currently protected through a combination of prior infection- and vaccine-induced immunity). Vaccine efficacy against symptomatic disease and infection after each dose (of Pfizer and Astra-Zeneca) were assumed as set out in Table 4. Our main analyses used the central efficacy assumptions. Two sensitivity analyses were performed, using 1) pessimistic vaccine efficacy assumptions and 2) lower adherence to the NPI measures retained after full NPI lifting (i.e. returning to a higher baseline transmissibility). We assumed an age-dependent vaccine uptake (Table 5).

Summary

1. Even if 4M vaccine doses a week are administered from 22 March onwards and assuming optimistic vaccine efficacy, only 29% of the population will be protected against disease due to vaccination by 26 April 2021, 44% by 31 May, 50% by 5 July and 51% by 2 August – the dates of full NPI lifting considered in scenarios 1 to 4 (Fig 1A). *Note these numbers reflect protection against disease from vaccination and are different to population immunity (which will increase from the current estimated level of 32%).*
2. NPIs must be slowly and cautiously lifted to minimise the number of deaths and prevent high hospital occupancy. Relaxing NPIs too quickly (scenario 1 or 2) will result in a peak hospital occupancy higher than or comparable to that currently experienced (Fig 1C) as well as substantial additional deaths (Fig 1D).
3. Scenario 3 or 4 are still predicted to result in a substantial additional number of deaths (57,600 (95%CrI 43,700 - 71,800) and 56,900 (95%CrI 44,100 - 71,600) respectively by June 2022) but with a lower peak hospital occupancy of ~15,000 patients, with scenario 3 peaking earlier (due to faster release of NPIs) than scenario 4.
4. If the assumed vaccination roll-out cannot be achieved, it is likely that scenario 3 will lead to worse outcomes than scenario 4.
5. Our results are highly dependent on the assumed (optimistic) vaccine efficacy, uptake, and roll-out speed. Due to the uncertainty surrounding these assumptions, it is critical to rapidly assess the true effectiveness of vaccination within the population as it may be lower than clinical efficacy reported in trial settings. Our results also assume no loss of infection- or vaccine-induced immunity on the time horizon of the analysis. Characterising the duration of vaccine-immunity will also be important.
6. With a lower vaccine efficacy, even scenarios 3 or 4 release would lead to a third wave of hospitalisations comparable in magnitude to the current wave (Fig 2-A2).
7. A return to higher transmissibility levels after NPIs are lifted will also lead to a third wave of hospitalisations comparable in magnitude to the current wave (Fig 2-A1). Therefore, whilst the impact of TTI, mask wearing, hand hygiene, and COVID security on R is difficult to quantify, it will be vital to emphasise the importance of normalising and ensuring adherence to all measures even after "full lifting" (stage 5) is achieved.
8. Given these sensitivities, it will be critical to assess the impact or each relaxation and update projections of the epidemic trajectory after each stage of relaxation before committing to the next phase. The impact of waning of immunity and of other new variants is particularly difficult to assess currently.

*Table 1: Summary of the four NPI easing scenarios where some restrictions are eased on specific dates resulting in an increase in transmissibility. The **incremental increase** in transmissibility at each stage is shown. For the overall transmissibility see Table 2.*

Date of NPI gradual release ("Full lift" still retains some baseline NPI measures such as TTI/hand hygiene)

Scenario 1. "Very fast"	**8 March '21**	**29 March '21**	**26 April '21**			
Level of NPI lifting	All schools	Tier 3 & 2	Full lift			
*Associated change in R**	+0.5	+0.5	+0.9 (moderate baseline NPIs) +1.9 (lower adherence to baseline NPIs)			
Scenario 2. "Fast"	**8 March '21**	**29 March '21**	**19 April '21**	**10 May '21**	**31 May '21**	
Level of NPI lifting	All schools	Tier 3	Tier 2	Tier 1	Full lift	
*Associated change in R**	+0.5	+0.1	+0.4	+0.1	+0.8 (moderate baseline NPIs) +1.8 (lower adherence to baseline NPIs)	
Scenario 3. "Medium"	**8 March '21**	**5 April '21**	**3 May '21**	**7 June '21**	**5 July '21**	
Level of NPI lifting	All schools	Tier 3	Tier 2	Tier 1	Full lift	
*Associated change in R**	+0.5	+0.1	+0.4	+0.1	+0.8 (moderate baseline NPIs) +1.8 (lower adherence to baseline NPIs)	
Scenario 4. "Gradual"	**8 March '21**	**5 April '21**	**3 May '21**	**7 June '21**	**5 July '21**	**2 Aug '21**
Level of NPI lifting	Primary schools	All schools	Tier 3	Tier 2	Tier 1	Full lift
*Associated change in R**	+0.25	+0.25	+0.1	+0.4	+0.1	+0.8 (moderate baseline NPIs) +1.8 (lower adherence to baseline NPIs)

** Here R denotes the reproduction number in the absence of immunity $R_{\_excl\_immunity}$, see methods "Definitions of the reproduction number" for definitions.*

Table 2: Overview of transmissibility associated with each tier-like restriction, accounting for immunity (R_{eff}) and excluding immunity ($R_{excl\_immunity}$) (see Methods "Definitions of the reproduction number"), assuming 68% of the population in England is currently susceptible to infection due to a combination of infection-induced and vaccine-induced immunity. See methods for definitions of R_{eff} and $R_{excl\_immunity}$

	$R_{\_excl\_immunity}$	R_{eff}
Current level	1.1	0.8
School reopening*	1.6	1.1
Tier 3	1.7	1.2
Tier 2	2.1	1.4
Tier 1	2.2	1.5
Baseline NPI^	3 (moderate baseline NPIs retained); 4 (lower adherence to baseline NPIs**)	2 (moderate baseline NPIs retained); 2.7 (lower adherence to baseline NPIs **)

* Refers to fully opening all schools. We assumed that opening primary schools only would lead to $R_{\_excl\_immunity}$ = 1.35 and R_{eff} = 0.95. ** "Lower adherence to baseline NPIs" values were used for sensitivity analyses only. ^Assumes some control such as TTI and hand hygiene continue.

Table 3: Pre-specified vaccination schedule (million doses per week)

Weeks commencing	Doses per week
1 Feb - 15 March	average 1.9 million
22 Mar 2021 onwards	4 million

Table 4: Vaccine efficacy assumptions for Astra-Zeneca (AZ, assumed to be 80% of the vaccine doses distributed) and Pfizer (PF, assumed to be 20% of the vaccine doses distributed)

	Vaccine	Central	Pessimistic*
Efficacy against disease	AZ (1 dose)	70%	56%
	AZ (2 dose2)	82.4%	70%
	PF (1 dose)	88%	88%
	PF (2 dose2)	94%	94%
Efficacy against infection	AZ (1 dose)	48%	24%
	AZ (2 dose2)	60%	30%
	PF (1 dose)	48%	48%
	PF (2 dose2)	60%	60%

* Pessimistic values were used for sensitivity analyses only.

Table 5: Vaccine uptake assumptions by group or age. Uptake was assumed to be the same for vaccine doses 1 and 2.

Group	Uptake
Care home residents (CHR)	95%
Care home workers (CHW)	85%
80+ years*	95%
50-80 years*	85%
<50 years*	75%

* not working or residing in a care home.

Caveats and Key assumptions

1. We assume **no loss of infection-induced or vaccine-induced immunity** on the time horizon of the analysis (*optimistic)*.
2. We assume that vaccine roll out pace of 4M doses/week from 22 March 2021 onwards can be maintained (*optimistic*)
3. We assume high vaccine uptake across all age groups (*optimistic*).
4. We **do not model any explicit effect of the vaccine on protection from severe disease or death** beyond that achieved from the knock-on effect of protection against infection and against symptomatic disease *(pessimistic).*
5. The gradual lifting of NPIs has been modelled as a step-wise increase in R. We do not model any specific policy change, rather an assumed change in the corresponding level of transmission. Note that there is **considerable uncertainty around those assumptions** *(unclear).*
6. We assume that mixing patterns under each Tier is the same as in autumn 2020 and these levels are fixed *(unclear)*.
7. We do not explicitly model school holidays *(unclear)*.
8. We assume **no correlation between vaccine uptake and risk of severe infection**. If uptake were to be lower in groups (e.g. ethnic groups) at higher risk of severe disease, our results would be too optimistic in terms of hospitalisations and deaths *(optimistic)*.
9. We **do not model differential infectivity of susceptibility by age** *(unclear)*.
10. We **do not model seasonality** which may have a potential impact on transmission (increased in winter, decreased in summer) *(unclear).*
11. We **do not model health care workers, social workers and individuals at risk** who may be prioritised for vaccination *(unclear).*
12. We assume **no dynamic replenishment of the care-home population** *(optimistic).*
13. We assume that some level of transmission control remains even after "fully lifting" NPIs at Stage 5 (Table 1) through measures such as TTI and hand hygiene *(optimistic)*.

Results

With the vaccine roll-out set out in Table 3, the proportion of the population protected against disease through vaccination will stabilise and plateau at around 52% during the summer 2021 (Figure 1A). This relatively low value stems from 1) not vaccinating the <18-year-olds, and imperfect vaccine 2) efficacy (see Table 4) and 3) uptake (see Table 5). ***[77.3% population eligible for vaccination x average 79.1% uptake amongst those eligible x 84.6% ("central") efficacy against disease with 2 doses = 52%].*** Note that this leaves a large pool of children (<18 years) who are not eligible for vaccination and who contribute to transmission.

With the uptake we assumed, it will take until 13 April 2021 to vaccinate all willing people in JCVI priority groups 1-9 (i.e. adults over 50) with a first dose of vaccine and until 6 June 2021 to administer the first dose of vaccine to all remaining willing adults. With an average 12 weeks between doses, we expect second doses to have been administered to JCVI priority groups 1-9 by mid-July 2021, and to all remaining adults by mid-September 2021.

Strategies (scenario 1 and 2 respectively) involving very rapid lifting of NPIs will lead to mixing and transmissibility increasing faster than population immunity, which will build-up incrementally until July (Figure 1A). This will lead to high values of the effective reproduction number *(R_{eff})* in the spring 2021 (Figure 1B), leading in turn to a large wave of infections, hospitalisations and deaths over the spring or summer 2021 (Figure 1C-D and Table 6).

Strategies (scenario 3 and 4 respectively) which lift NPI more gradually will lead to increases in mixing that are closer to being offset by the increases in population immunity (Figure 1A),

leading to lower values of the effective reproduction number in the spring 2021 (Figure 1B). These lifting strategies will still lead to a resurgence of transmission but with peak of hospitalisations and deaths predicted to be smaller than seen in January 2021 (Figure 1C-D and Table 6). Note that with the assumed vaccine roll-out, scenarios 3 and 4 have similar cumulative numbers of hospital admissions and deaths, as the “full” NPI lifting step occurs at comparable levels of vaccine protection in the population (Figure 1A). However, the timing of the peak will be later with scenario 4 lifting, following a summer with very little epidemic activity, compared with scenario 3. Although the magnitude of peak hospitalisations is marginally lower in scenario 3 (due to higher levels of infection-induced immunity) than 4, there is considerable uncertainty around these estimates, and the difference is not significant. Critically, with a slower vaccine roll-out we would expect scenario 3 to lead to more hospitalisations and deaths than scenario 4.

Our results depend on the underlying assumptions about mixing/transmissibility after NPI lifting (see Table 2) and vaccine efficacy (see Table 4). Assuming more pessimistic values for either of those would lead to a third wave of hospitalisations and deaths of magnitude comparable or even worse than the current one (Figure 2).

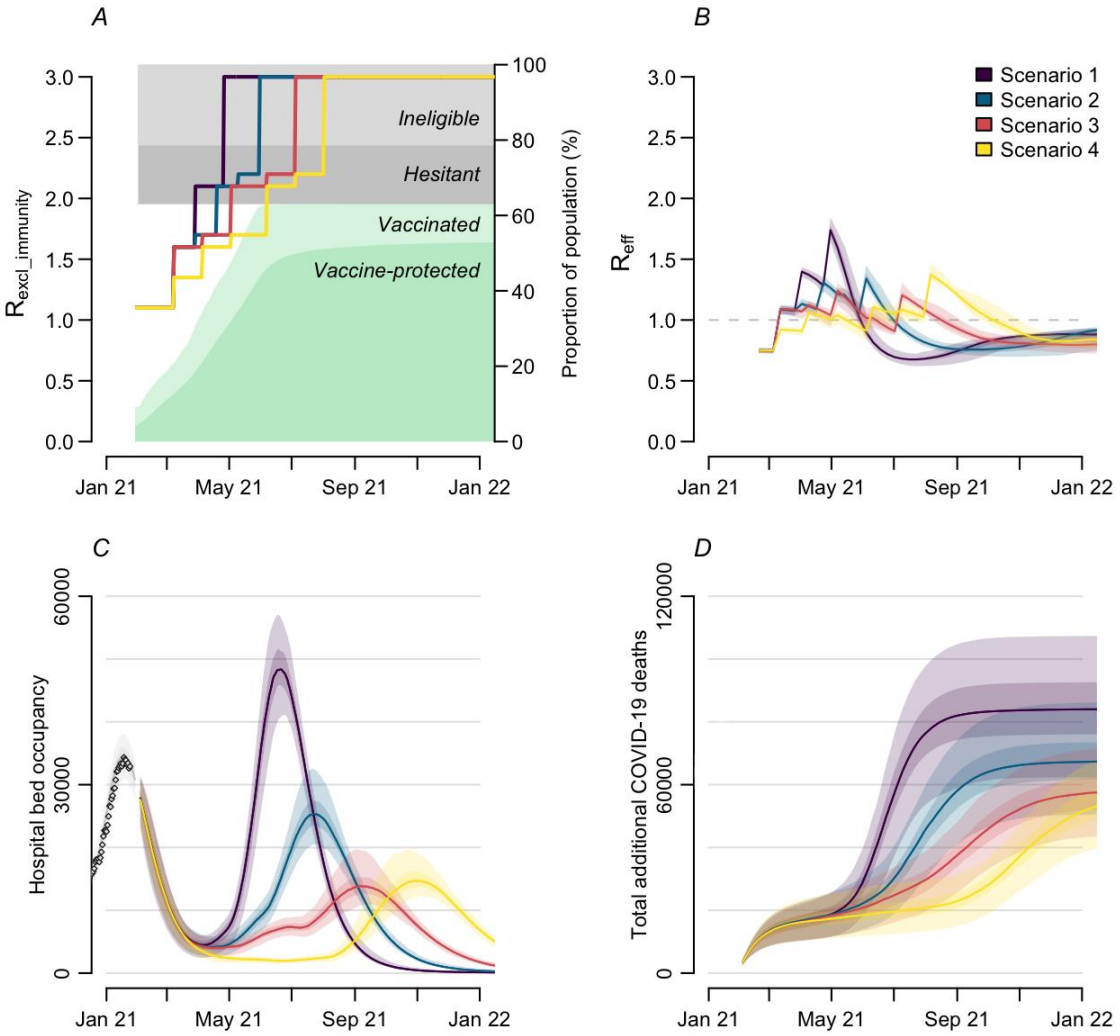

Figure 1: Impact of vaccine roll-out and NPI lifting on the epidemic dynamic in England. *(A) Increase in mixing (measured as $R_{\_excl\_immunity}$, coloured lines, left axis) under different release strategies over time and proportion of the population in England protected against disease through vaccination over time (dark green shading, right axis) and vaccinated (having received one dose) over time (light green shading, right axis)(see Table 4). The grey shaded areas show the proportion of the population ineligible for vaccination (i.e. <18 years, light grey, right axis) and those who are vaccine hesitant and not taking the vaccine (dark grey, right axis) (see Table 5). (B) Effective reproduction number over time under different release strategies. (C) COVID-19 hospital occupancy (general wards and ICU) and (D) cumulative COVID-19 deaths (counted from 1st Feb 2021) under different release strategies. In panel C, the points at the start (Jan 21) show the recent reported data and the grey line the model fit. The release strategies considered are scenario 1 (purple), 2 (blue), 3 (pink), and 4 (yellow) as set out in Table 1. This figure shows results assuming moderate baseline measures are retained after NPI lifting (see Table 2), "central" vaccine efficacy, and vaccine roll-out and uptake described in Tables 3 and 5. See methods for definitions of R_{eff} and $R_{excl\_immunity}$.*

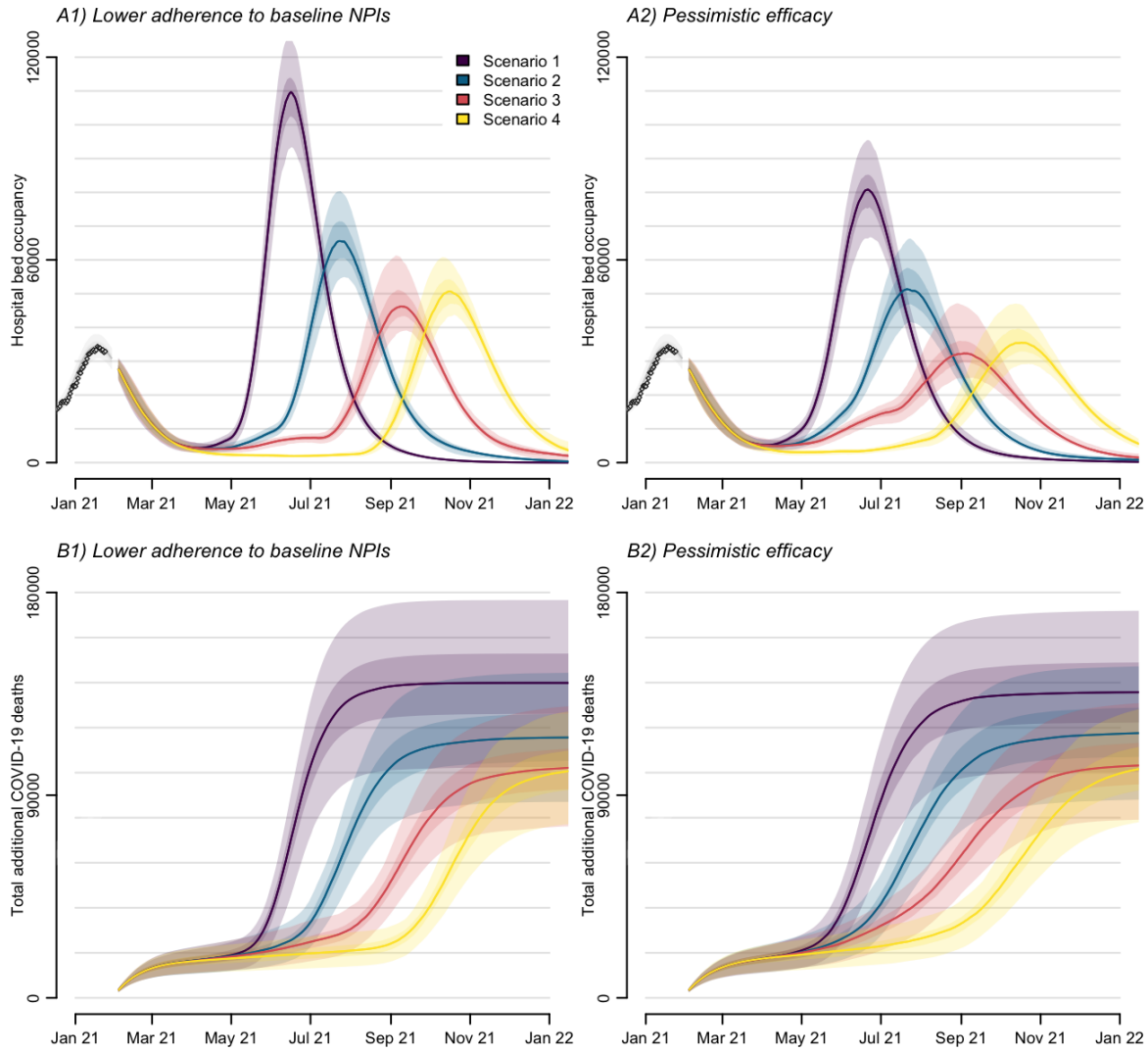

Figure 2: Sensitivity analyses. *England COVID-19 (top: A1 and A2) hospital occupancy (general wards and ICU) and (bottom: B1 and B2) cumulative deaths (counted from 1st Feb 2021) assuming scenario 1 (purple), 2 (blue), 3 (pink), and 4 (yellow) release of NPIs over time as set out in Table 1, with vaccine roll out and uptake assumptions as in Tables 3 and 5 respectively. A1 and B1 assume a higher transmissibility level after NPIs are "fully" lifted (lower adherence to baseline NPIs) ($R_{excl\_immunity}$ = 4) as shown in Table 2. A2 and B2 assume a "pessimistic" vaccine efficacy as set out in Table 4. The points at the start of panel A1 and A2 (Jan 21) show the recent reported data and the grey line the model fit. Note the y-axis scale is different to that in Figure 1C-D.*

Table 6: Cumulative deaths between 1st February 2021 and 30th June 2022 under different vaccination scenarios considered. Values shown are mean (95% CrI) and are all rounded to the nearest hundred.

Analysis type	NPI lifting scenario	Transmissibility after lifting NPIs $R_{\_excl\_immunity}$*	Vaccine efficacy**	Cumulative number of deaths by 30 June 2022 (95% CrI)	Cumulative hospital admissions up to 30 June 2022 (95% CrI)	Cumulative incidence up to 30 June 2022 (95% CrI)	Peak hospital occupancy up to 30 June 2022 (95% CrI)
Main analysis	1	3	Central	83,500 (61,900 - 106,600)	341,000 (302,700 - 371,000)	16,179,600 (15,609,500 - 16,703,900)	48,900 (41,100 - 57,100)
	2			67,100 (50,000 - 85,700)	269,000 (244,000 - 287,700)	13,199,100 (12,506,500 - 14,087,200)	25,700 (20,500 - 32,600)
	3			57,600 (43,700 - 71,800)	227,700 (209,300 - 241,300)	11,403,400 (10,080,200 - 12,818,100)	14,400 (11,000 - 19,800)
	4			56,900 (44,100 - 71,600)	222,700 (204,800 - 235,300)	11,178,200 (9,968,200 - 12,523,600)	15,200 (12,400 - 19,700)
Varying Transmissibility after NPI lifting	1	4	Central	139,000 (101,900 - 175,800)	568,200 (503,300 - 619,100)	24,270,700 (23,335,000 - 25,431,900)	109,000 (93,600 - 125,900)
	2			115,300 (86,600 - 143,600)	465,800 (415,800 - 506,900)	20,948,900 (19,839,800 - 21,916,900)	66,400 (55,000 - 80,400)
	3			102,800 (76,500 - 129,600)	413,600 (369,000 - 448,200)	19,230,000 (18,391,600 - 20,093,700)	47,600 (39,100 - 61,400)
	4			104,300 (77,700 - 131,400)	417,300 (377,000 - 444,200)	19,300,300 (17,226,800 - 20,493,700)	51,100 (43,800 - 60,800)
Varying vaccine efficacy	1	3	Pessimistic	135,500 (99,900 - 171,100)	531,600 (468,200 - 583,300)	21,514,600 (20,377,700 - 22,845,500)	80,900 (66,700 - 95,800)
	2			118,200 (87,900 - 147,500)	459,400 (405,500 - 502,100)	19,309,900 (17,834,200 - 20,706,800)	52,400 (41,600 - 66,400)
	3			105,000 (78,900 - 132,600)	405,800 (363,000 - 441,400)	17,536,700 (16,447,800 - 18,568,100)	33,500 (25,200 - 47,100)
	4			105,400 (82,100 - 133,800)	404,500 (366,300 - 433,800)	17,452,900 (16,504,800 - 18,195,800)	36,500 (29,600 - 47,100)

* $R_{\_excl\_immunity}$ used after NPI relaxation (see Tables 1 and 2 and text for detail). ** See table 4 for details.

Supplementary Results

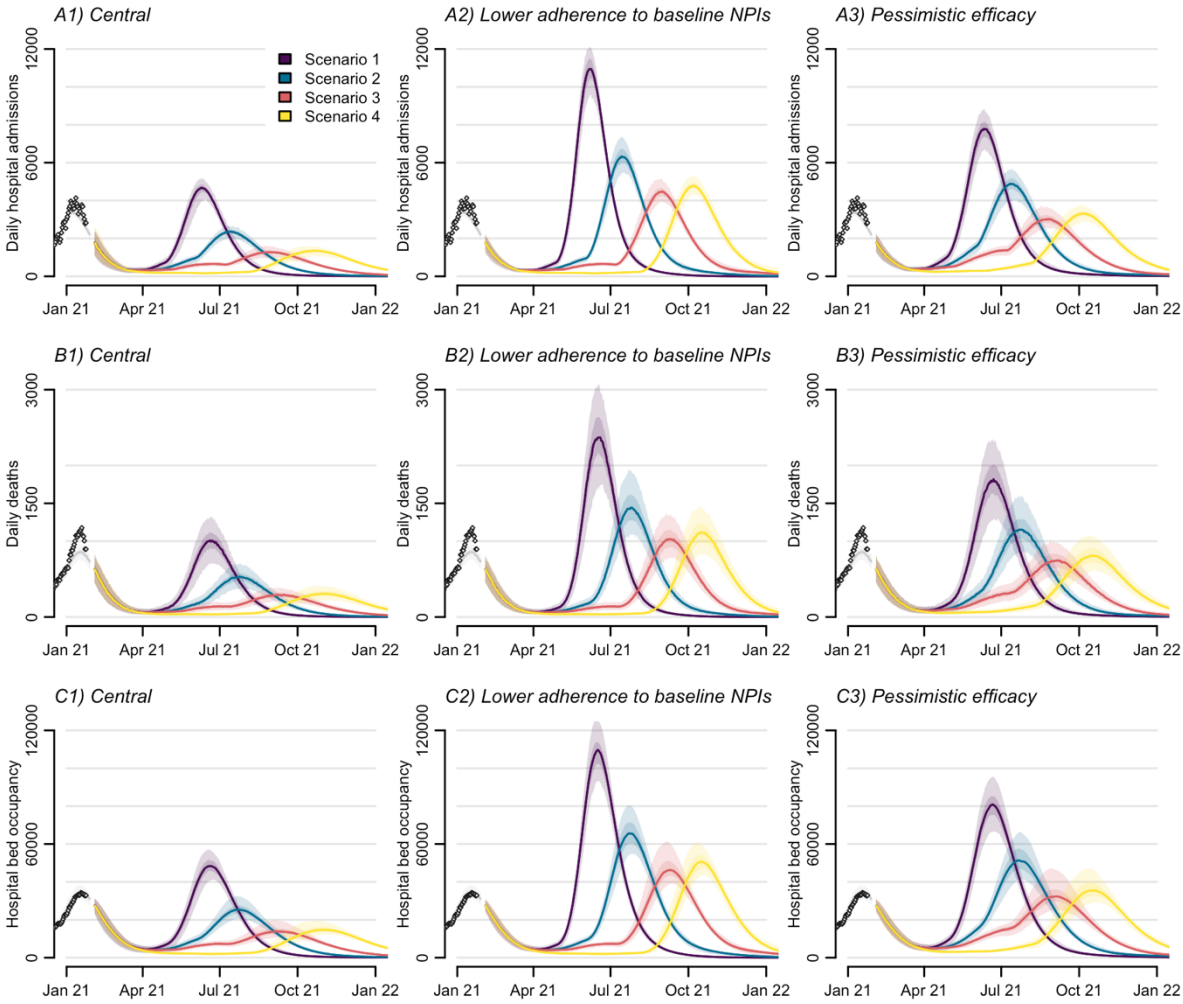

Figure S1: *England COVID-19 daily (A1-A3) hospital admissions, (B1-B3) deaths and (C1-C3) hospital occupancy assuming scenario 1 (purple), 2 (blue), 3 (pink), and 4 (yellow) release of NPIs over time as set out in Table 1. A1-C1 show our main analysis with a "central" transmissibility after NPI lifting where moderate baseline NPIs are retained (see Table 2), "central" vaccine efficacy (see Table 4), and vaccine roll-out and uptake described in Tables 3 and 5. A2-C2 show sensitivity analyses assuming a higher transmissibility level after NPIs are "fully" lifted with lower adherence to baseline NPIs ($R_{excl\_immunity}$ = 4) as shown in Table 2. A3-C3 show sensitivity analyses assuming a "pessimistic" vaccine efficacy as set out in Table 4. The points at the start of the panels (Jan 21) show the recent reported data and the grey line the model fit. Note the y-axis scale is different to that in Figure 1C-D.*

Methods

We used a stochastic compartmental model of SARS-CoV-2 transmission fitted to multiple data streams from each NHS region in England. The model is stratified into 17 five-year age groups (0-4, 5-9, …, 75-79, 80+), a group of care home residents (CHR) and a group of care home workers (CHW). The model has been described in detail elsewhere (https://www.medrxiv.org/content/10.1101/2021.01.11.21249564v1). The model was extended to include vaccination where each compartment in the model is further stratified to account for vaccination status. We used parameter values calibrated to data from the 29th January 2021. The model was fitted with vaccination as reported.

Definitions of the reproduction number

Throughout, we consider two definitions of the reproduction number:

- The reproduction number in the absence of immunity, $R_{excl\_immunity}$, defined as the average number of secondary infections that an infected individual would generate in a large population with no immunity. $R_{excl\_immunity}$ depends on the virulence of the pathogen and the contact patterns in the population, but not the level of population immunity. We use different values of $R_{excl\_immunity}$ to reflect different levels of mixing associated with different levels of restrictions, irrespective of the level of immunity in the population (see next section).
- The effective reproduction number, R_{eff}, defined as the average number of secondary infections that an infected individual will generate with current levels of population immunity. R_{eff} depends on the virulence of the pathogen, the contact patterns in the population and the level of immunity in the population. We use R_{eff} to characterise the extent to which the epidemic is under control, with $R_{eff} > 1$ in a growing epidemic and $R_{eff} < 1$ in a declining epidemic.

$R_{excl\_immunity}$ and R_{eff} are linked through the proportion of the population who is immune (because of infection- or vaccine-induced immunity) p_{immune}, with $R_{eff} = R_{excl\_immunity} * (1-p_{immune})$.

Transmissibility associated with Tiers

We modelled 6 levels of restrictions from 1 (lowest level of restrictions) to 6 (highest). These have been matched to the ask and what has been implemented in the past during this pandemic. While we cite policies in place during the Tier system implemented last autumn, we do not model any specific policy change but instead an assumed change in the corresponding level of transmission.

- Level 1: Baseline NPIs with T&T, hand washing & masks and some Covid secure measures in places such as public transport and crowded indoor spaces;
- Level 2: Similar to tier 1, i.e. rule of six in place, working from home when possible, hospitality curfew;
- Level 3: Similar to tier 2, i.e. measures from level 2 plus no indoor mixing between households and travel reduced;
- Level 4: Similar to tier 3, i.e. measures of level 3 plus local travel only, and pubs and bars closed;
- Level 5: Similar to the autumn lockdown, i.e. measures of level 4 plus non-essential shops being closed;
- Level 6: Full lockdown with schools closed.

We assume that going from level 6 to level 5 (opening schools) will increase $R_{\_excl\_immunity}$ by +0.5 (+0.25 if opening only primary schools). This is based on the consensus value from SPI-M accounting for the increase in transmission due to the B.1.1.7 variant.

The impact of switching from level 5 to 4 is difficult to quantify but is likely to be small, and we assume an increase of +0.1 in $R_{\_excl\_immunity}$.

To model the change of transmission between level 4, 3 and 2, we used the analysis by Laydon et al. (unpublished, previously presented at SPI-M) which estimated level 3 and 4 as having respectively 94% and 74% of the level of transmission of level 2.

Finally, the final baseline transmissibility ($R_{\_excl\_immunity}$) once all NPIs are lifted is assumed to be 3, consistent with an increased in transmissibility due to B.1.1.7 but with a slightly lower level of transmission due to baseline NPIs. Due to the uncertainty in predicting the behaviour of individuals after the lifting of most of the restrictions, we also consider a baseline $R_{\_excl\_immunity}$ of 4 as a sensitivity analysis.

1st dose vaccine roll-out

We assume first doses were delivered in England between 8th December 2020 and 29th January 2021 as reported in data received from PHE and DHSC via SPI-M. We then assume a vaccine dose roll out as in Table 3. To account for second doses, we assumed that the number of available first doses on a given day is given by the total available doses on that day and subtract the number of first doses administered 84 days (12 weeks) prior. If the resulting value was negative, this was set to 0. From 30th January onwards, we assumed first doses are split between NHS regions in proportion of their population size. We assumed a mixture of 20% of Pfizer and 80% of AstraZeneca vaccine doses are distributed, with no difference between age groups or care home workers and residents being modelled.

We assume doses are distributed in priority order to:

1. Care home workers and residents
2. Individuals 50 or over by decreasing 5-year age band priority
3. Individuals under 50

Children under 18 years are not vaccinated. As our model is stratified using 5-year age classes, we model the vaccination of individuals aged 18-19 by assuming the uptake in the 15-19 age group is 2/5 of the uptake in other groups under 50 years old.

2nd dose vaccine roll out and vaccine efficacy after each dose

We assume degree-type protection from vaccination: all vaccinees have their likelihood of acquiring infection reduced by a factor of (*1 – vaccine efficacy*).

For each compartment in the model, 4 successive vaccination stages (duration of each stage and efficacy of vaccine in each stage are shown on Figure S2):

- Unvaccinated
- Vaccinated with 1st dose before onset of vaccine efficacy
- Vaccinated with 1st dose with full efficacy from 1st dose – this includes individuals having received the second dose before the onset of efficacy of the second dose
- Vaccinated with 2nd dose with full efficacy from 2nd dose

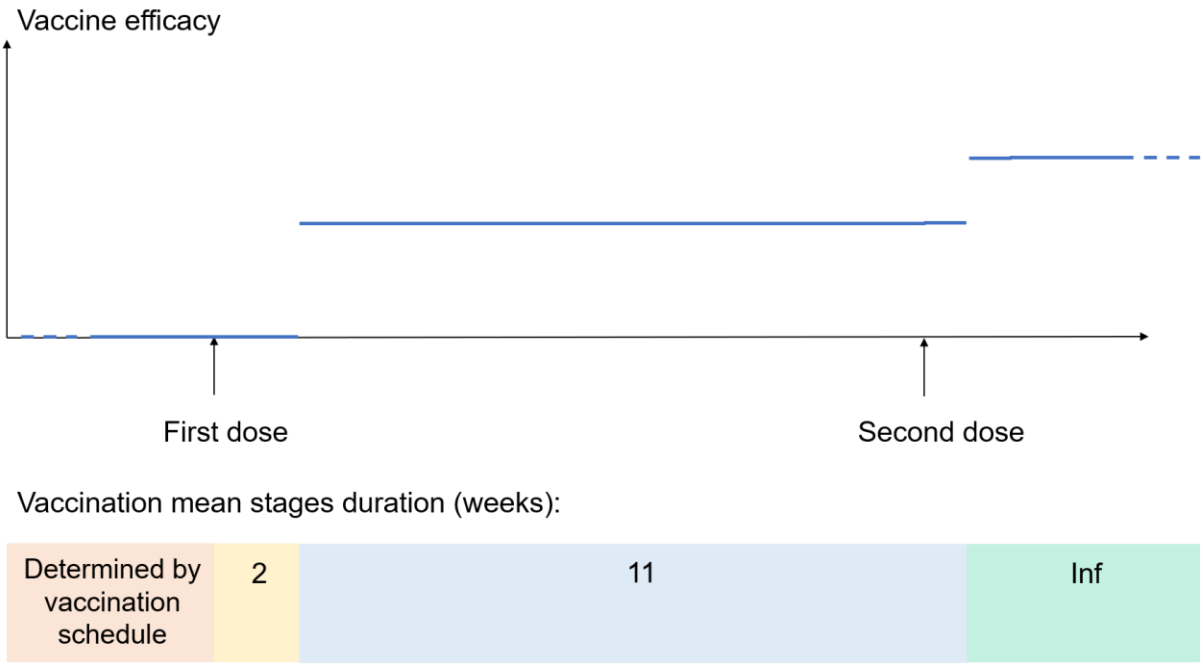

Figure S2: Vaccination stage duration and associated vaccine efficacy. The lower panel depicts mean duration of vaccination stages in weeks (numbers denote number of weeks in each stage). The top panel shows the associated vaccine efficacy and delays to protection over time.

Vaccine efficacy after first and second dose was varied across scenarios (see Table 4) but we assume:

- No efficacy in the 14 days following the first dose
- No efficacy of the second dose for the 7 days following dose 2

Phase 2 PF and AZ vaccine trial results indicated substantial increase in immunogenicity only after 14 days post-dose 1, and 7-days post-dose 2[1,2]. We therefore assumed a 14-day (respectively 7-day) delay between receiving the first (respectively second) dose and the onset of dose-specific efficacy.

Vaccine efficacy

We assumed that the vaccine has two effects:

1. Efficacy *against infection,* e_{inf}: Reducing the risk of infection in vaccinated individuals, compared to those not vaccinated.
2. Efficacy *against symptoms conditional on infection,* e_{sympt}: Reducing the risk of symptoms in vaccinated individual who become infected, compared to those non vaccinated who become infected.

Those two effects combined reduce the risk of symptomatic infection ("Efficacy *against symptomatic infection,* e_{clin}", non-conditional on infection) in vaccinated individuals, compared to those not vaccinated.

Values of efficacy for both e_{clin} and e_{inf} are shown in Table 4. The reduction in the risk of being symptomatically infected (e_{clin}), as reported in clinical trials, is determined by both the

[1] Mulligan et al. (2020). https://www.nature.com/articles/s41586-020-2639-4
[2] Ramasamy et al. (2020). https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)32466-1/fulltext

reduction in the risk of being infected (e_{inf}) and the reduction in the risk of becoming symptomatic if infected (e_{sympt}) as follows:

$$e_{clin} = e_{inf} + (1 - e_{inf}) * e_{sympt}$$

We therefore calculated e_{sympt} as:

$$\boldsymbol{e_{sympt} = (e_{clin} - e_{inf}) / (1 - e_{inf})}$$

Vaccine uptake

We assume vaccine uptake was age dependant, as shown in Table 5. We assumed every individual having received their first dose would go on to also receive a second dose.