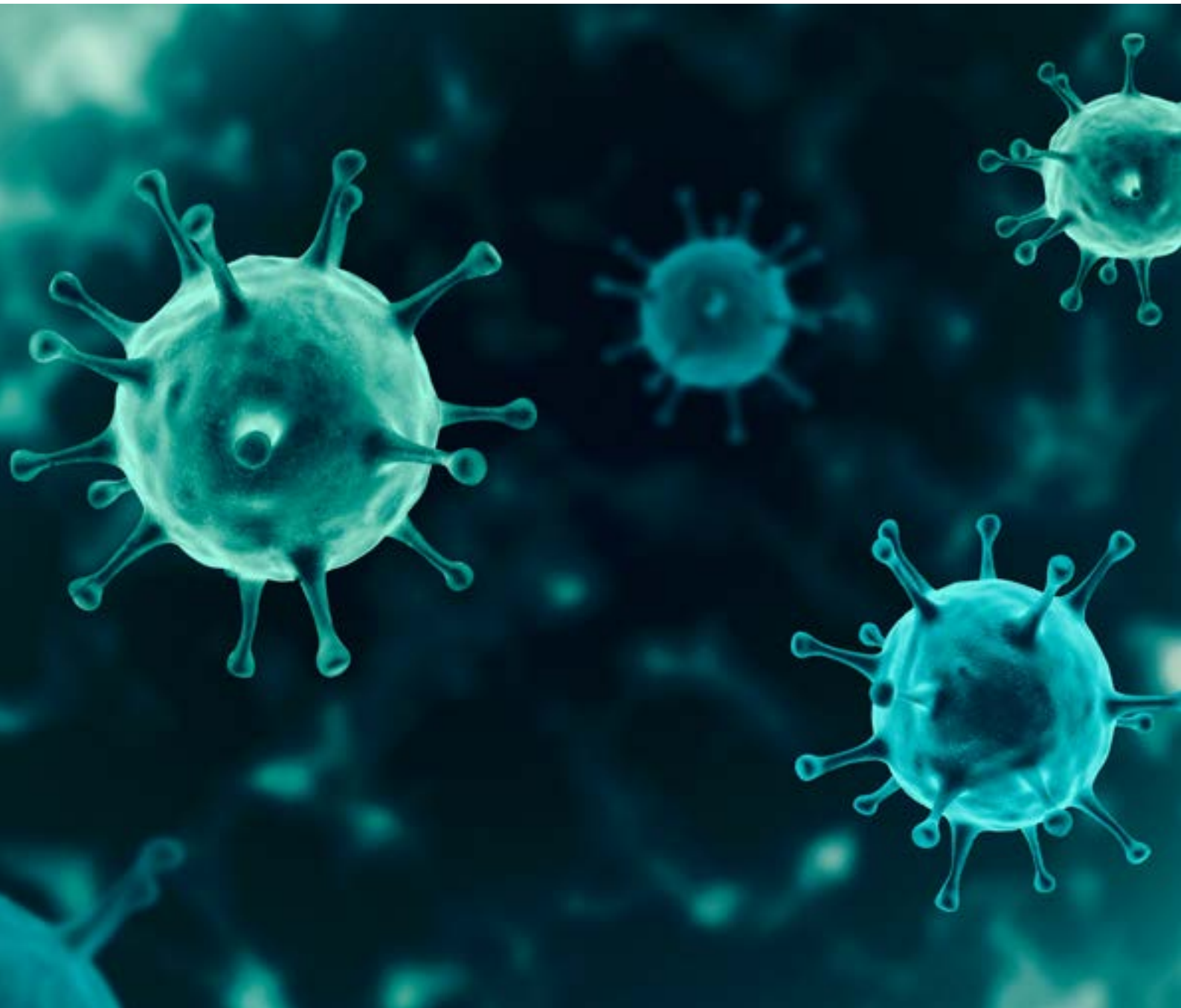
University of Adelaide/SAHMRI SA COVID-Ready modelling

80% vaccination coverage



Introduction

We report on modelling commissioned by SA Health to inform decisions regarding the South Australian COVID Transition Plan. In particular, the modelling provides an indication of the probable scale of Ward and ICU occupancy for three scenarios under consideration. In all scenarios borders are opened (to double-vaccinated individuals) at 80% vaccination coverage and vaccination is assumed to continue to be rolled-out based on projections of recent vaccination rates until an age group reaches c. 95% vaccination coverage, and it is assumed that the policy measures remain in place throughout the period of 300 days.

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Executive Summary

With realistic TTIQ in place:

- Maintaining current PHSM (i.e., Activity Restrictions) is estimated to be able to manage the Ward and ICU demand from COVID-19 infections generated in the community.

- Relaxing restrictions from current PHSM poses a risk to being able to manage the Ward and ICU demand from COVID-19 infections generated in the community, with:

    - A chance of approximately 15% – 22% of exceeding ICU capacity if current PHSM remain in place except for facemasks in general settings not mandated; and,
    - A chance of approximately 79% – 89% of exceeding Ward capacity and 81% – 92% of exceeding ICU capacity if current PHSM remain in place with the use of Vaccine Passports (to allow higher-risk activities by double-vaccinated individuals) with partial compliance (at 75% compliance).

- Figure 1 and Table 1 report the following statistics under scenarios considered:

    - Peak Cases (peak daily new cases of all types);
    - Peak Admissions (peak new daily Hospital Admissions);
    - Peak Ward (peak Ward Occupancy beds);
    - Peak ICU (peak ICU Occupancy beds); and,
    - Peak Deaths (peak new daily Deaths).

  and Figure 2 and Table 1 report Total Deaths.

- The scenario representing the removal of mandated facemasks in general settings can alternatively be viewed as a scenario in which current PHSM remains unchanged but transmission potential is higher than expected (i.e., near the 90th percentile of our estimate). It follows there is some risk of exceeding ICU capacity even if current PHSM remains in place and borders are opened at 80% vaccination coverage.

University of Adelaide and SAHMRI (2021). SA COVID-Ready modelling: 80% vaccination coverage. SAHMRI & University of Adelaide.
https://sahmri.org.au/research/programs/health-policy-centre

Summary of scenario and results

The three scenarios considered, and an executive summary of outcomes, are:

Scenario 1 – 80% vaccination coverage in adults, current PHSM (Figure 3):

- Borders are opened to double-vaccinated individuals at 80% vaccination coverage (16+).
- Restrictions as per current Activity Restrictions.
- The Transmission Potential (TP) used was the median estimate of TP as of 17/10/21[1].

  The chance of an outbreak – that is averaging more than 100 cases per day over any three-day period – is estimated to be 27%. Note the importance of attempting to maintain Optimal TTIQ in conjunction with these policy settings, with the chance of an outbreak estimated to increase to 68% if Partial TTIQ was used only.

  In the event of an outbreak, this scenario is estimated to be manageable with respect to hospital capacity (noting here and throughout only median estimates of all parameters, including TP, are used):

  - Peak Ward Occupancy – 36 [21, 78] (median [95% confidence interval]) beds – and extremely small chance of demand exceeding 200 ward beds;
  - Peak ICU Occupancy – 9 [5, 19] beds – and extremely small chance of demand exceeding 30 ICU beds; and,
  - Total Deaths (over the 300 days) – 13 [4, 51] individuals.

  Given the particular relevance of this scenario, we also consider explicitly the Peak Ward Occupancy and Peak ICU Occupancy for those aged 0-11:

  - Peak Ward Occupancy (0–11 years) – 7 [2, 21] beds; and,
  - Peak ICU Occupancy (0–11 years) – 1 [0, 5] beds.

1. This is from the University of Adelaide's forecasting model which contributes to an ensemble forecast reported weekly to AHPPC/CDNA as part of National Situational Assessment. Please see Technical Appendix for further details.

Scenario 2 – 80% vaccination coverage in adults, current PHSM without facemasks (Figure 4):

- Borders are opened to double-vaccinated individuals at 80% vaccination coverage (16+).
- Restrictions as per current Activity Restrictions except for facemasks in general use not mandated.
- Removal of facemasks was assumed to increase Transmission Potential by 10%.[2]
- Note that this scenario can alternatively be viewed as a scenario in which current PHSM remains unchanged but TP is higher than expected (i.e., near the 90th percentile of our estimate).
- The chance of an outbreak is estimated to be 64%.
- In the event of an outbreak, this scenario is estimated to present risks to being able to manage cases in particular with respect to ICU capacity:
  - Peak Ward Occupancy – 70 [23, 203] beds – and a 3% chance of demand exceeding 200 Ward beds;
  - Peak ICU Occupancy – 18 [6, 47] beds – and a 20% chance of demand exceeding 30 ICU beds; and,
  - Total Deaths (over the 300 days) – 55 [6, 186] individuals.

Scenario 3 – 80% vaccination coverage in adults, current PHSM, Vaccine Passports (partial compliance) (Figure 5):

- Borders are opened to double-vaccinated individuals at 80% vaccination coverage (16+).
- Restrictions as per current Activity Restrictions.
- Vaccine Passports for double-vaccinated individuals to engage in higher-risk activities, and with partial compliance by unvaccinated individuals at 75% compliance.
- TP used for 75% of unvaccinated and single-vaccinated individuals was the median estimate of TP as of 17/10/21, and the TP used for double-vaccinated and 25% of unvaccinated and single-vaccinated individuals was the median estimate of TP with facemasks and baseline PHSM only.[3]

  The chance of an outbreak is estimated to be 84%.

  In the likely event of an outbreak, this scenario is estimated to present risks to being able to manage cases in particular with respect to Ward and ICU capacity:

  - Peak Ward Occupancy – 351 [24, 585] beds – and an 85% chance of demand exceeding 200 Ward beds;
  - Peak ICU Occupancy – 72 [6, 119] – and an 87% chance of demand exceeding 30 ICU beds; and,
  - Total Deaths (over the 300 days) – 315 [8, 424] individuals.

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2. Please see Technical Appendix for further details.

3. This is from the University of Adelaide's forecasting model which contributes to an ensemble forecast reported weekly to AHPPC/CDNA as part of National Situational Assessment. Please see Technical Appendix for further details.

Model notes and caveats

Full details of our model and assumptions are provided in the Technical Appendix.

Note the Cases reported in the top row of Figures 2 - 4 is daily new cases and is cases of all types; to be emphatic, daily new cases reported from the model are not equivalent to active cases. The composition of cases regarding vaccinated versus unvaccinated, and symptomatic versus asymptomatic, and the fraction officially recorded (case ascertainment, and hence active cases) will be dependent on the realised contact-tracing efficiency and testing behaviour of the population.

We note again that all scenarios assume there is no change to the Activity Restrictions during a simulated outbreak.

Introduced cases are not counted in case numbers and do not contribute to Ward and ICU Occupancy numbers. It will be important to estimate the number of infected arrivals once borders open – which requires information on flight volumes and current COVID cases for each source jurisdiction – to also add such cases contributions to Ward and ICU beds. Similarly, we have not considered export of our cases which would hence not potentially require local management.

Note that the variability reported arises from intrinsic variability in the events of transmission, hospitalisation, requiring ICU, lengths of stay in hospital, et cetera, but for fixed (median or mean) parameter values. Each parameter used in this study has associated uncertainty, including the Transmission Potential (TP), and hence the true uncertainty in estimates is very large. Small changes in TP, within uncertainty ranges that exist, in the upward direction can result in substantial changes, and hence it is advised to err on the conservative side with respect to not exceeding hard capacity constraints. To be emphatic, the estimated impact of removing facemasks results in a median TP that is within the likely distribution of values for estimated TP including facemasks.

The model does not account for heterogeneity in vaccination coverage, which will likely see an earlier and larger peak in Ward and ICU Occupancy. The model does not account for waning immunity, nor boosters. These act in opposite directions and are hopefully approximately neutralised. The model does not include the use of antivirals which may assist in reducing hospitalisations, and progression to critical care. It appears too early to trade-off use of antivirals with Activity Restrictions, but in the future this might be possible.

Figure 1

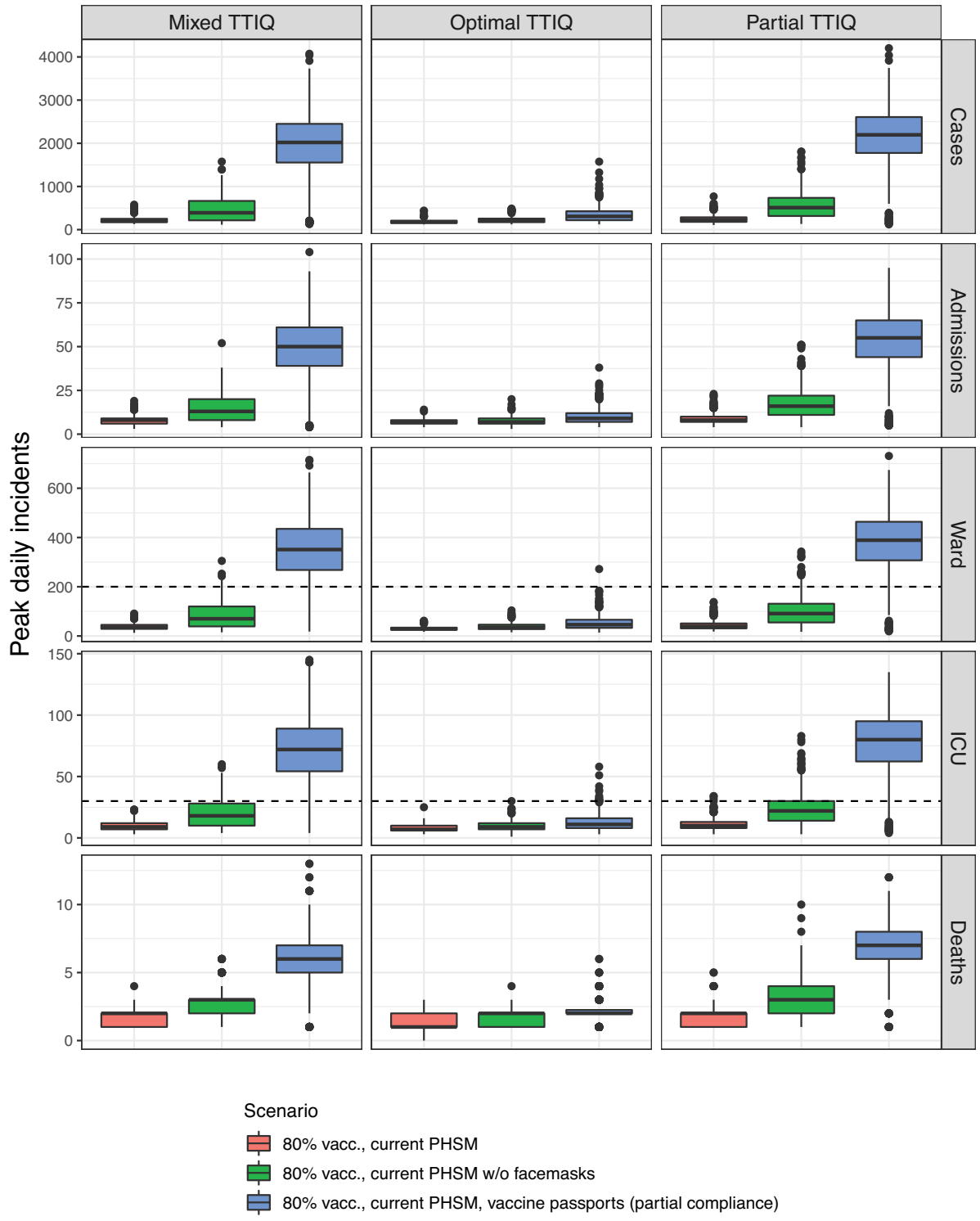

Figure 1. Boxplots of epidemic statistics by Scenario (colour). The dashed line for Ward corresponds to 200 beds and the dashed line for ICU corresponds to 30 beds. Boxes illustrate the inter-quartile range (i.e., the distance between the 25th and 75th percentiles of the data). The lower/upper whiskers extend to the lowest/highest value within 1.5 times the inter-quartile range of the box. Data beyond the end of the whiskers are plotted as points.

Table 1

Scenario	Cases	Admissions	Ward	ICU	Deaths	Total Deaths
80% adults vaccinated, current PHSM	202 [139,476]	8 [4,16]	36 [21,78]	9 [5,19]	2 [1,3]	13 [4,51]
80% adults vaccinated, current PHSM w/o facemasks	391 [146,1087]	13 [5,31]	70 [23,203]	18 [6,47]	3 [1,5]	55 [6,186]
80% adults vaccinated, current PHSM, Vaccine Passports (partial compliance)	2020 [169,3182]	50 [6,81]	351 [24,585]	72 [6,119]	6 [1,10]	315 [8,424]

Table 1. Peak daily incidence (median [95% confidence interval]) of daily new infected Cases, hospital Admissions, Ward occupancy, ICU occupancy, and daily new Deaths, and Total Deaths, under different scenarios. This corresponds to results presented in Figures 1 and 2.

Figure 2

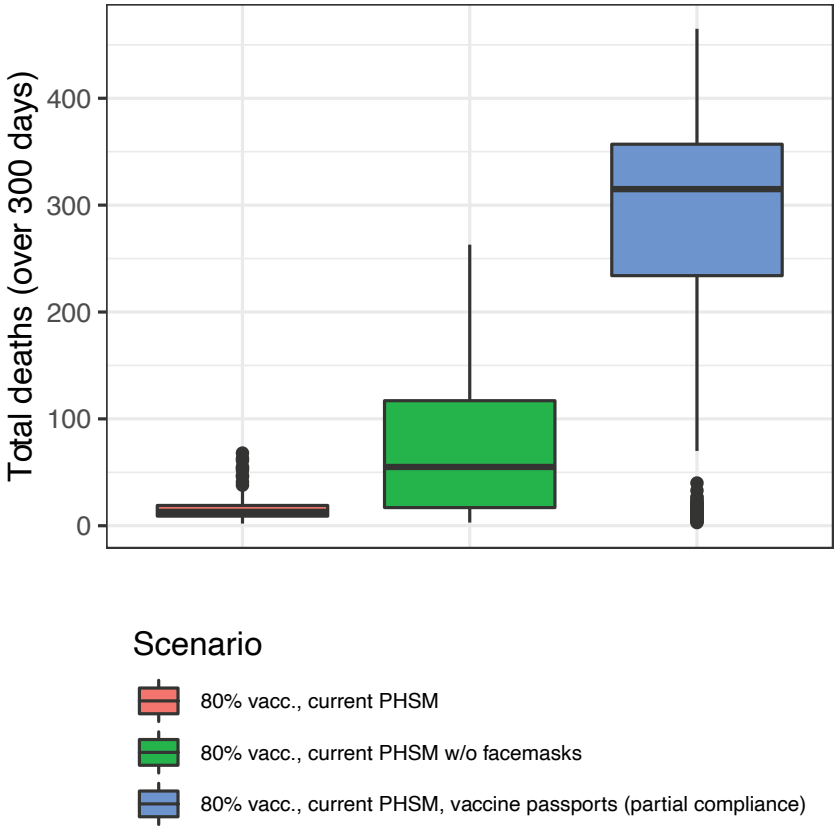

Figure 2. Boxplots of Total Deaths (over 300 days) by Scenario (colour). Boxes illustrate the inter-quartile range (i.e., the distance between the 25th and 75th percentiles of the data). The lower/upper whiskers extend to the lowest/highest value within 1.5 times the inter-quartile range of the box. Data beyond the end of the whiskers are plotted as points.

Scenario 1 – 80% vaccination coverage in adults, current PHSM

(Note: Peak numbers cannot be read from the median trajectory as this does not reflect the true peak seen in any given simulation. Peak numbers should be read from Figure 1 and Table 1.)

Figure 3

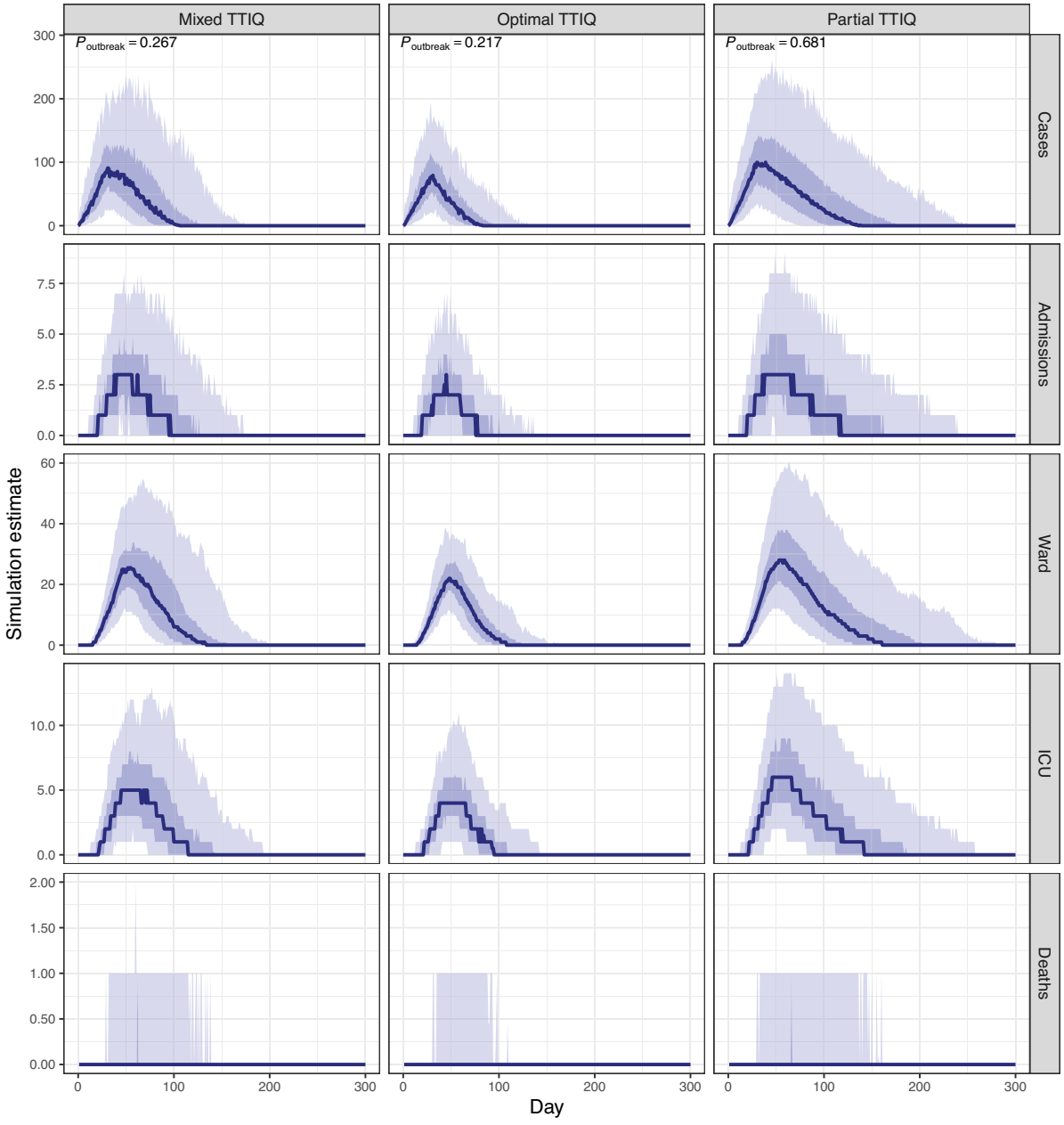

Figure 3. Median (± 95 % confidence intervals) simulation trajectories under the mixed, optimal and partial TTIQ scenarios, over the course of a 300-day simulation. These simulations are conditional on a COVID-19 outbreak occurring, which was defined as a simulation run in which ≥ 100 new cases per day were produced over three consecutive days. For each scenario, panels illustrate: (a) daily incidence of new cases (of all symptomatic and vaccination statuses); (b) daily admissions of COVID-19 patients to hospital; (c) occupancy in a hospital ward; (d) occupancy of intensive care units (ICU); and (e) daily deaths. In the top row, the probability of an outbreak occurring is also reported.

Scenario 2 – 80% vaccination coverage in adults, current PHSM without facemasks

(Note: Peak numbers cannot be read from the median trajectory as this does not reflect the true peak seen in any given simulation. Peak numbers should be read from Figure 1 and Table 1.)

Figure 4

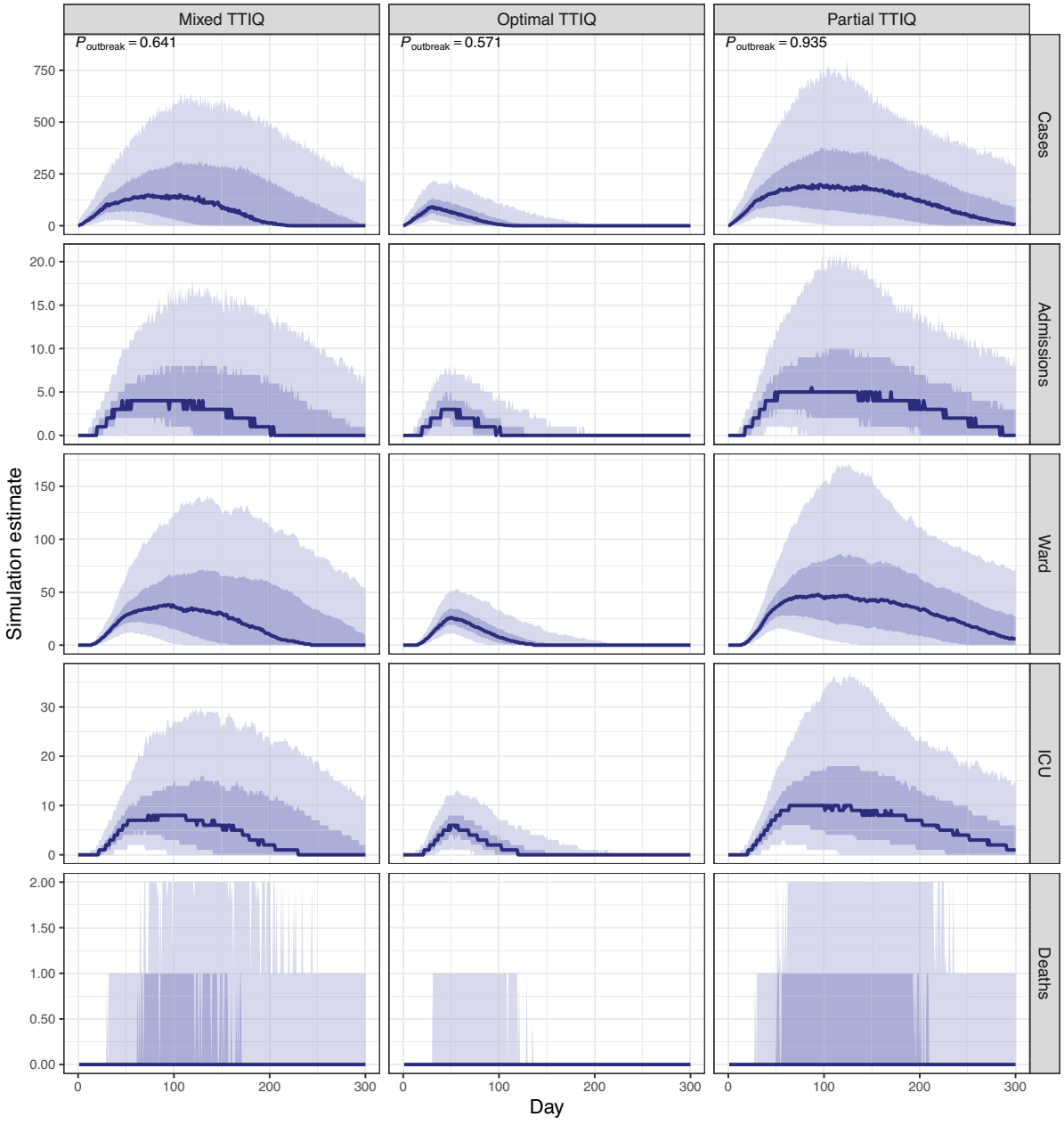

Figure 4. Median (± 95 % confidence intervals) simulation trajectories under the mixed, optimal and partial TTIQ scenarios, over the course of a 300-day simulation. These simulations are conditional on a COVID-19 outbreak occurring, which was defined as a simulation run in which ≥ 100 new cases per day were produced over three consecutive days. For each scenario, panels illustrate: (a) daily incidence of new cases (of all symptomatic and vaccination statuses); (b) daily admissions of COVID-19 patients to hospital; (c) occupancy in a hospital ward; (d) occupancy of intensive care units (ICU); and (e) daily deaths. In the top row, the probability of an outbreak occurring is also reported.

Scenario 3 – 80% vaccination coverage in adults, current PHSM, Vaccine Passports (partial compliance)

(Note: Peak numbers cannot be read from the median trajectory as this does not reflect the true peak seen in any given simulation. Peak numbers should be read from Figure 1 and Table 1.)

Figure 5

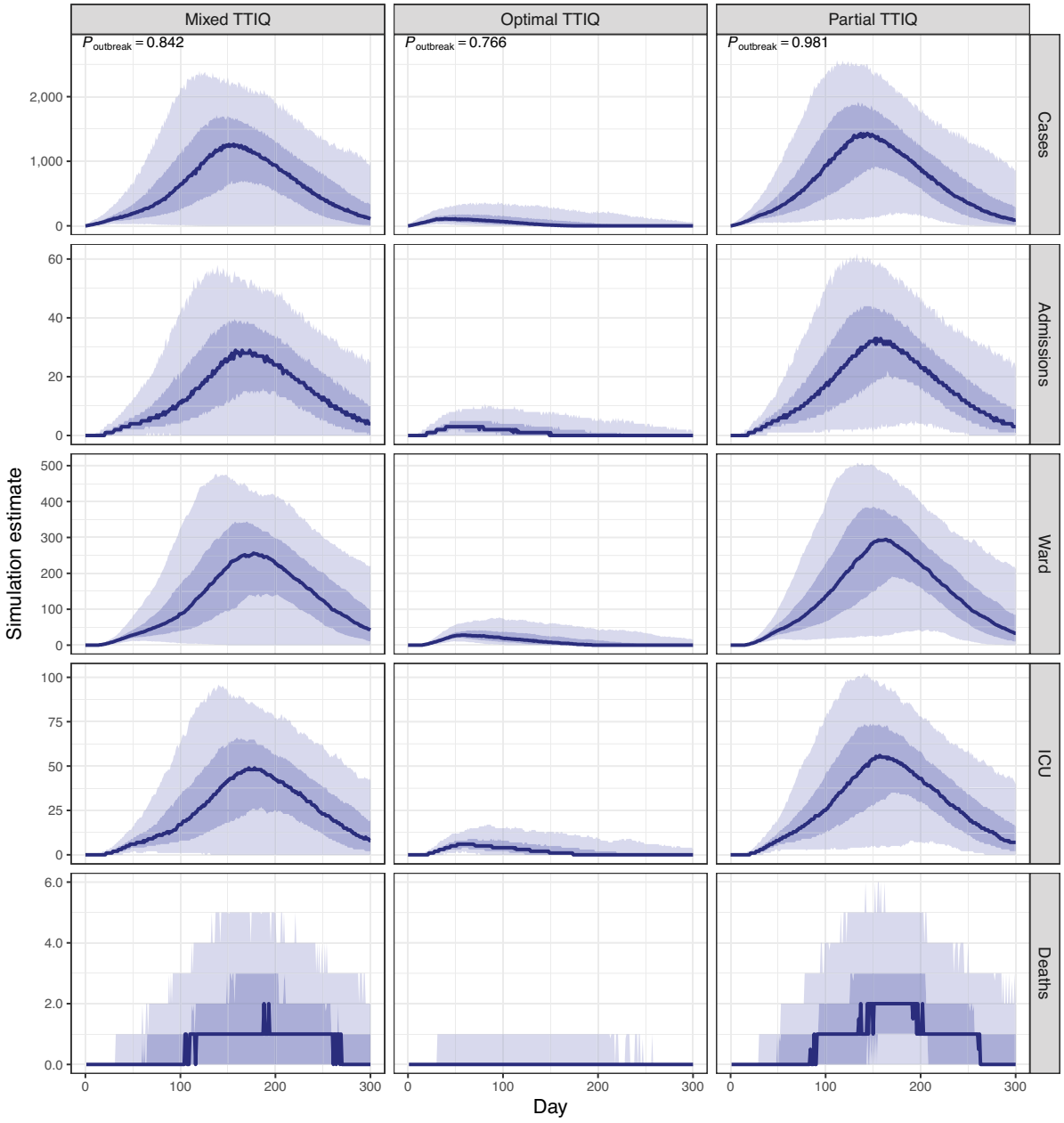

Figure 5. Median (± 95 % confidence intervals) simulation trajectories under the mixed, optimal and partial TTIQ scenarios, over the course of a 300-day simulation. These simulations are conditional on a COVID-19 outbreak occurring, which was defined as a simulation run in which ≥ 100 new cases per day were produced over three consecutive days. For each scenario, panels illustrate: (a) daily incidence of new cases (of all symptomatic and vaccination statuses); (b) daily admissions of COVID-19 patients to hospital; (c) occupancy in a hospital ward; (d) occupancy of intensive care units (ICU); and (e) daily deaths. In the top row, the probability of an outbreak occurring is also reported.

Technical Appendix

Overview of the individual-based model of epidemic dynamics

We constructed an age-structured, individual-based model to simulate the trajectory of a COVID-19 outbreak in South Australia. The model assumed a state-wide population size of 1,778,839 individuals split into 10 age classes[4]. Contact rates (and consequently the potential for SARS-CoV-2 transmission) varied between pairs of age classes, but no spatial structure has been included. The model was run on a daily timestep, and simulated individuals as they moved through different vaccination states and were potentially infected with SARS-CoV-2. Infected individuals then passed through a number of 'filters' governed by probabilities of transmitting the virus to others, becoming symptomatic for COVID-19, requiring hospitalisation, requiring ICU treatment, and dying. All probabilities specified were a function of age and vaccination status, and we assumed a parameterisation based on information for the Delta strain of the SARS-CoV-2 virus. The model was coded in R (v. 4.3.0) software for statistical computing, and due to stochasticity inherent in the model process, c. 600 simulation iterations were run for each scenario modelled. In all simulations, median or mean estimates of all parameters were used only.

Vaccine coverage scenarios and trajectories

We scraped age-structured vaccine coverage data for South Australia from the federal Department of Health's daily updates on COVID-19 data for Australia (https://www.health.gov.au). These data were used to fit a statistical model for the proportion single- or double-vaccinated individuals in each of 18 age classes over time, which assumed a maximum of between 95% and 97% coverage could feasibly be reached in each age class. Allowing some variation in the maximum possible coverage for each age class improved the fit of the model to the vaccination data. The model was then used to forecast age-structured vaccination coverage into the future (Fig. A1). These forecasts predicted the date of reaching 80% double-vaccination coverage for over 16-year-olds as 29th November 2021.

To explore the impact of easing restrictions once this threshold is reached, we used the model forecasts of vaccine coverage to define starting age-structured vaccination proportions for simulation scenarios initiated at 80% coverage for over 16-year-olds. For simplicity, we assumed all individuals less than age 60 years received the Pfizer vaccine and all those 60 years and older receive the AstraZeneca vaccine. Using this approach, all individuals in the simulated population were assigned to one of initial five vaccination states: unvaccinated, or vaccinated with 1 Pfizer dose, 2 Pfizer doses, 1 AstraZeneca dose, or 2 AstraZeneca doses. Future growth in vaccination coverage was simulated based on the model forecasts, by updating the vaccination states of a random selection of simulated individuals each day as required to match forecast changes in vaccine coverage (Fig. A1).

4. Population size and age stratification estimates from Data SA – Population projections – Medium series 2016-2041; https://data.sa.gov.au/data/dataset/population-projections-for-sa/resource/dfd605f7-ea87-4f12-a650-6ee90630471c.

Figure A1

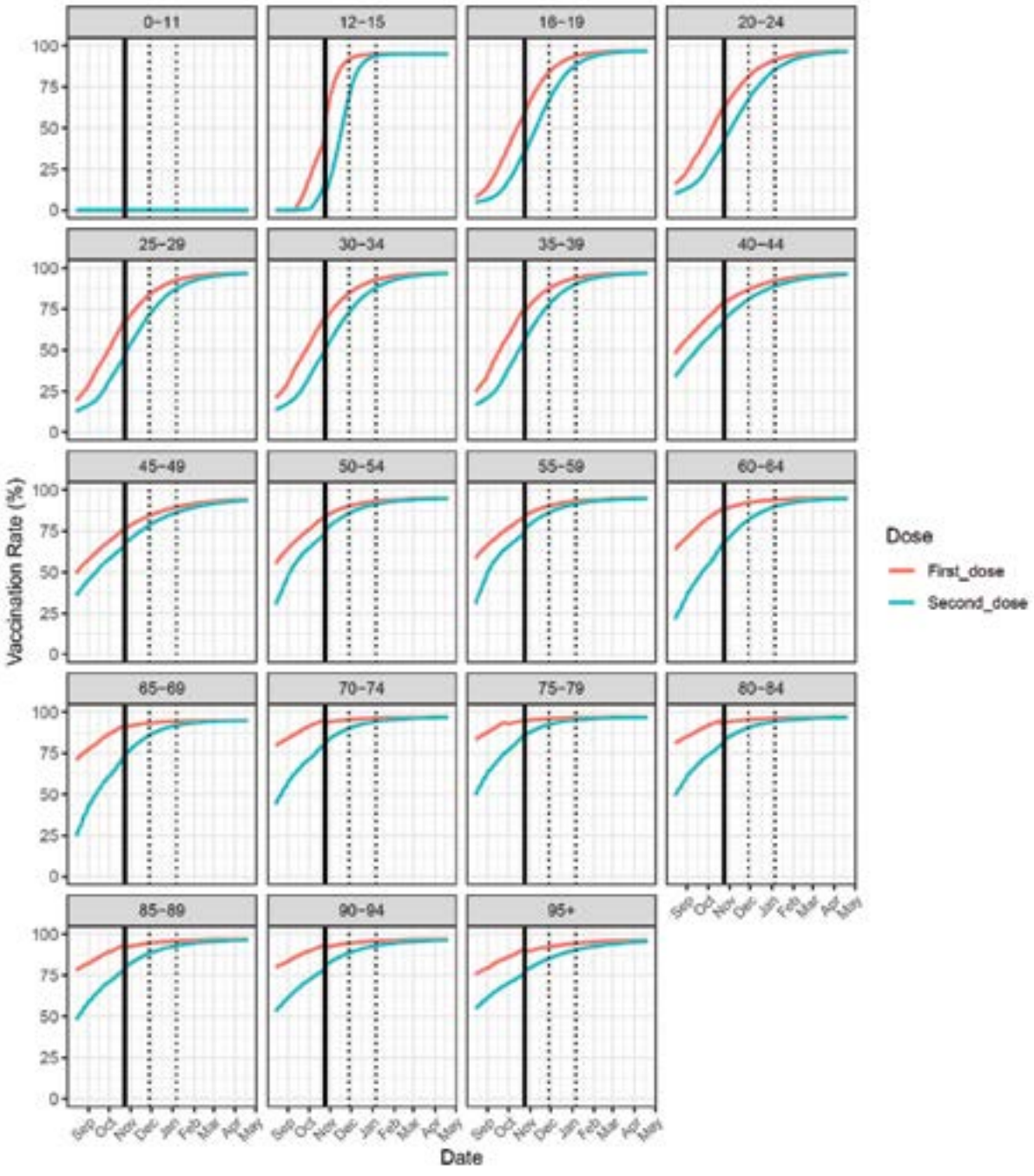

Figure A1. Age-structured vaccination coverage trajectories used in the individual-based simulation model. The thick back vertical line indicates the break between the raw data scraped from https://www.health.gov.au (up until 24th October 2021) and the model forecasts developed in this report. The two dotted vertical lines indicate the date at which 80% and 90% double-vaccination coverage of over 16-year-olds is predicted to be reached, respectively.

Introduction of SARS-CoV-2

To provide the conditions required for a COVID-19 epidemic, we simulated the introduction of 20 COVID-positive cases per day for the first 30 days (i.e., 600 cases in total). We sampled a time-since-infection for each introduced positive case based on empirical data for other locations and assumed these cases could be symptomatic or asymptomatic.

We note that these introduced cases are not counted in case numbers and do not contribute to Ward and ICU Occupancy numbers. Similarly, we have not considered export of our cases which would hence not potentially require local management.

Mixing between age classes

To account for differing contact rates (and therefore transmission) between pairs of age classes, we constructed an age-structured mixing matrix for the South Australian population. Using the age class distribution assumed above, we estimated a 10 × 10 mixing matrix using the R package conmat (https://njtierney.github.io/conmat), which in turn estimates mixing matrices in four settings (school, work, home and 'other') and combines these into a single representative mixing matrix. The resultant mixing matrix is shown in Fig. A2.

Figure A2

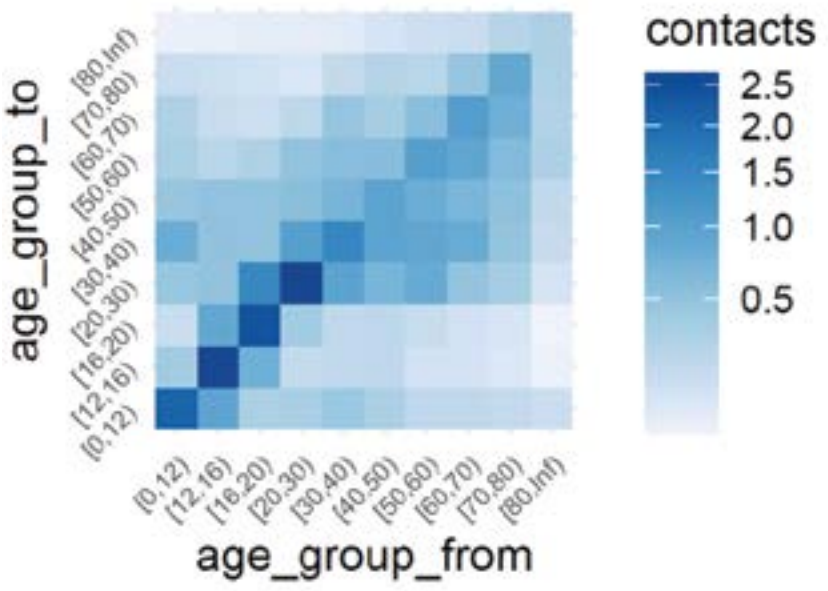

Figure A2. The age-structured mixing (contact) matrix used for the South Australian population.

Transmission

Our transmission potential (as used in Scenario 1) is estimated for South Australia as of 17th October 2021. This estimation is as part of National Situational Assessment Forecasting that we contribute to on a weekly basis and reported to Australian Health Principal Protection Committee (AHPPC); the PHSM effects (as used in Scenario 3) are estimated from this model too[5]. TTIQ is informed by NSW and Vic. data, previous Doherty reports, and discussions with SA Health. This TP is reduced for asymptomatic individuals, by vaccination, and by TTIQ, as described below.

Scenario 1 – 80% vaccination coverage in adults, current PHSM

In this Scenario we used the median estimate of the current (as of 17th October 2021) TP in South Australia. The TP estimate was 1.95 [1.60,2.31] (median [95% confidence interval]) with the effect of vaccination removed. We then modified this to account for TTIQ effect (see below for details of TTIQ), and then for age-specific mixing, symptomatic proportions, and age-structured susceptibilities.

Scenario 2 – 80% vaccination coverage in adults, current PHSM without facemasks

In this Scenario, the median TP estimate used in Scenario 1 was increased by 10% to account for the removal of facemasks from public health orders[6]; hence, the TP used was 2.15[7]. We then modified this to account for TTIQ effect (see below for details of TTIQ), and then for age-specific mixing, symptomatic proportions, and age-structured susceptibilities.

Scenario 3 – 80% vaccination coverage in adults, current PHSM, Vaccine Passports (partial compliance)

In this Scenario, the TP used for 75% of unvaccinated and single-vaccinated individuals was the median estimate of current TP (i.e., TP = 1.95 as estimated on 17/10/21 and used in Scenario 1), and the TP used for double-vaccinated and 25% of unvaccinated and single-vaccinated individuals was the median estimate of TP with baseline PHSM and facemasks only. The higher TP used for 25% of unvaccinated and single-vaccinated individuals represents a scenario of only 75% compliance with the vaccine passport system amongst this group. Baseline TP is estimated from current TP as follows. The combined effect of the South Australian's behavioural changes to macro-distancing

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5. Details of the basis of this estimation and the forecasting model are reported in https://www.doherty.edu.au/uploads/content_doc/Technical_Report_15_March_2021_RELEASED_VERSION.pdf. An updated version of this methodology should appear in the near future.

6. This estimate is based primarily upon the evidence synthesis in Miller C, Dono J, Wesselingh S. (2021) Masks in Community Settings – COVID-19 Evidence Update. SAHMRI. https://www.sahmri.org/covid19/, the best available international evidence in Abaluck, Jason et al. , "The Impact of Community Masking on COVID-19: A Cluster Randomized Trial in Bangladesh" (2021). Cowles Foundation Discussion Papers. 2642 https://elischolar.library.yale.edu/cowles-discussion-paper-series/2642, and the estimate in Australia from C. Valentina, R. MacIntyre (2021) The Impact of Universal Mask Use on SARS-COV-2 in Victoria, Australia on the Epidemic Trajectory of COVID-19. Frontiers in Public Health 9, 307: 10.3389/fpubh.2021.625499. The evidence base is limited and uncertainty regarding this estimate is high. Effectiveness varies with compliance, and between surgical versus cloth masks, and while expert advice suggests the effect in Australia is likely in the region of 5%–15%, with extremely high uptake estimates have been as large as 22%–33% (Scott N, Saul A, Spelman T, Stoove M, Pedrana A, Saeri A, et al. (2021) The introduction of a mandatory mask policy was associated with significantly reduced COVID-19 cases in a major metropolitan city. PLoS ONE 16(7): e0253510. https://doi.org/10.1371/journal.pone.0253510).

7. Please note that the TP used in this Scenario is contained within the 95% confidence interval of the current TP (as relevant to Scenario 1); hence, the realisations produced in Scenario 2 could be realised under Scenario 1 simply because of randomness/uncertainty in the underlying TP and its estimation.

(as measured by Google mobility data) and micro-distancing (a survey of compliance to the 1.5m social distancing rule) as influenced by current Activity Restrictions was estimated to reduce TP by about 27% (on 17/10/21)[8]. We assume that the behaviours of Vaccine Passport holders (or those behaving as holders of such) would be similar to those of an individual without Activity Restrictions applied to them (with the exception of facemasks in general use). Hence, the TP used for double-vaccinated individuals and 25% of unvaccinated and single-vaccinated individuals was TP = 1.95/(1-0.27) = 2.67. We then modified this to account for TTIQ effect (see below for details of TTIQ), and then for age-specific mixing, symptomatic proportions, and age-structured susceptibilities. Transmission.

Our transmission potential (as used in Scenario 1) is estimated for South Australia as of 17th October 2021. This estimation is as part of National Situational Assessment Forecasting that we contribute to on a weekly basis and reported to Australian Health Principal Protection Committee (AHPPC); the PHSM effects (as used in Scenario 3) are estimated from this model too . TTIQ is informed by NSW and Vic. data, previous Doherty reports, and discussions with SA Health. This TP is reduced for asymptomatic individuals, by vaccination, and by TTIQ, as described below.

To convert the TP of an individual to the daily timestep of the model, we used a generation interval distribution (Fig. A3) to partition the expected number of new cases generated from a single infected individual for each day post-infection[9]. By combining the adjusted case-specific TPs and the daily component of a case's generation interval distribution, together with the age-structured mixing matrix, the expected number of new infections arising in each age class of the population due to contact with each infected individual was calculated. To account for heterogeneity in transmission, we then generated an integer number of new cases arising from each infected individual, by sampling from a negative binomial distribution with mean equal to the expected number of new cases from that individual and overdispersion parameter k = 0.2[10].

Figure A3

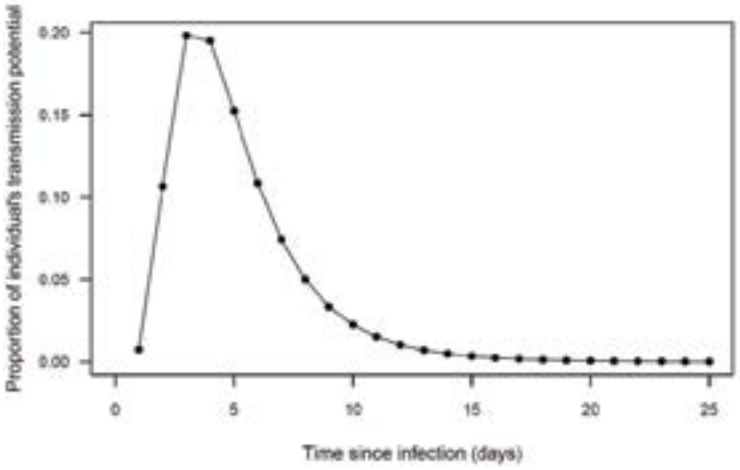

Figure A3. Generation interval distribution up to day 25 post-infection.

8. Note that the estimate of the reduction of TP from PHSM is also subject to large uncertainty and we use a median estimate only.

9. Generation interval informed by estimates in Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. Int J Infect Dis 2020;93:284–6.

10. The overdispersion parameter is informed by estimates in Endo A; Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, Abbott S, Kucharski AJ, Funk S. Estimating the overdispersion in COVID-19 transmission using outbreak sizes outside China. Wellcome Open Res. 2020 Jul 10;5:67. doi:10.12688/wellcomeopenres.15842.3.

Susceptibility

There is strong evidence that susceptibility to SARS-CoV-2 infection varies with age. Age-structured susceptibilities used in the model are shown in Table A1[11].

Table A1

Age	Susceptibility
0-9	0.28
10-19	0.38
20-29	0.79
30-39	0.86
40-49	0.80
50-59	0.82
60-69	0.88
70-79	0.74
80+	0.74

Table A1: Baseline probabilities of acquiring a SARS-CoV-2 infection upon contact with an infected individual (i.e., susceptibilities).

11. These estimates are based upon Davies, N.G., Klepac, P., Liu, Y. et al. Age-dependent effects in the transmission and control of COVID-19 epidemics. Nat Med 26, 1205–1211 (2020). https://doi.org/10.1038/s41591-020-0962-9, and Doherty consortium revised estimates using ONS Study data (https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveypilot/15october2021#age-analysis-of-the-number-of-people-who-had-covid-19).

Symptomatic and asymptomatic cases

The model accounted for variation in the transmission and disease severity between symptomatic and asymptomatic cases. The age-structured probabilities of expressing symptoms (conditional on infection) are provided in Table A2[12]. Asymptomatic individuals were assumed to have 50% the Transmission Potential of symptomatic individuals, regardless of their age class[13]. For symptomatic cases, we sampled a time to symptom onset from infection in days from a lognormal(1.63, 0.5) incubation period distribution[14].

Table A2

Age	P(symptomatic)
0-9	0.6
10-19	0.4
20-29	0.5
30-39	0.6
40-49	0.6
50-59	0.65
60-69	0.65
70-79	0.75
80+	0.75

Table A2: Baseline probabilities of being symptomatic given infection.

12. These estimates are informed by the published Clinical Fraction estimates in Davies et al. (see footnote 4), but adjusted based upon estimates in other published studies (e.g., Hinch R, Probert WJM, Nurtay A, Kendall M, Wymant C, Hall M, et al. (2021) OpenABM-Covid19—An agent-based model for non-pharmaceutical interventions against COVID-19 including contact tracing. PLoS Comput Biol 17(7): e1009146. https://doi.org/10.1371/journal.pcbi.1009146), estimates of overall symptomatic fractions in conjunction with Australian age-stratified case data, and sympathetic to baseline probabilities of hospitalisation (see Table A4).

13. This is a common assumption, used in our National Situational Assessment forecasting model, and as assumed in the Doherty Institute National Plan modelling.

14. McAloon C, Collins Á, Hunt K, et al. Incubation period of COVID-19: a rapid systematic review and meta-analysis of observational research. BMJ Open 2020;10:e039652. doi: 10.1136/bmjopen-2020-039652.

Vaccination

As detailed above, the model assumed a specific starting vaccination coverage and future vaccination trajectory, split by vaccine type and dose number. The proportional reduction due to vaccination in the probability of infection, symptom development, onward transmission, hospitalisation and death is provided in Table A3[15]. However, given the lag between vaccination and the development of immunity, we assumed the impact of vaccination lagged ten days behind the date of each vaccination dose.

Table A3

Vac-dose	Infection	Symptoms	OT (sympt.)	OT (asympt.)	Hospitalisation	ICU	Death
None	0	0	0	0.5	0	0	0
AZ-1	0.25	0.35	0.05	0.5	0.70	0.70	0.69
AZ-2	0.62	0.65	0.25	0.575	0.85	0.85	0.90
P-1	0.41	0.40	0.10	0.5	0.70	0.70	0.70
P-2	0.75	0.83	0.50	0.65	0.91	0.91	0.91

Table A3: Proportional reduction in infection, symptoms, onward transmission (OT) given symptomatic, OT given asymptomatic, hospitalisation, ICU admission (conditional on hospitalisation) and death, by vaccine and doses.

15. These estimates are informed by international literature, in particular the study of Pouwels, K.B., Pritchard, E., Matthews, P.C. et al. Effect of Delta variant on viral burden and vaccine effectiveness against new SARS-CoV-2 infections in the UK. Nat Med (2021). https://doi.org/10.1038/s41591-021-01548-7 based on the ONS Study in the UK, but also Sheik A et al. SARS-CoV-2 Delta VOC in Scotland: demographics, risk of hospital admission, and vaccine effectiveness (Correspondence). Lancet 2021; 397: 10293, P2461-2. https://doi.org/10.1016/S0140-6736(21)01358-1, Eyre et al. The impact of SARS-CoV-2 vaccination on Alpha & Delta variant transmission. medRxiv (2021). https://doi.org/10.1101/2021.09.28.21264260, and Andrews et al. Vaccine effectiveness and duration of protection of Comirnaty, Vaxzevria and Spikevax against mild and severe COVID-19 in the UK. medRxiv (2021). https://doi.org/10.1101/2021.09.15.21263583, and to ensure consistency with other model assumptions.

TTIQ

We simulate the reduction in onwards transmission due to TTIQ activities in one of three ways: (1) Optimal TTIQ, representing the efficacy of TTIQ when daily new case numbers are less than 35 cases per day averaged over three days; (2) Partial TTIQ, representing "stretched" TTIQ with reduced effectiveness when daily new case numbers are greater than 100 cases per day averaged over three days; and (3) Mixed TTIQ, which on average linearly interpolates the reduction in onward transmission based upon the number of daily new case numbers / day averaged over the previous three days.

The TTIQ was simulated by sampling from different distributions of the time-to-isolation, and isolated cases were assumed not to contribute to further onwards transmission of the virus. These time-to-isolation distributions are illustrated in Figure A4[16], for the optimal and partial TTIQ and for symptomatic and asymptomatic individuals. The Optimal TTIQ reduces infection by 50% on average, while the Partial TTIQ reduces infection by 30% on average.[17]

Figure A4

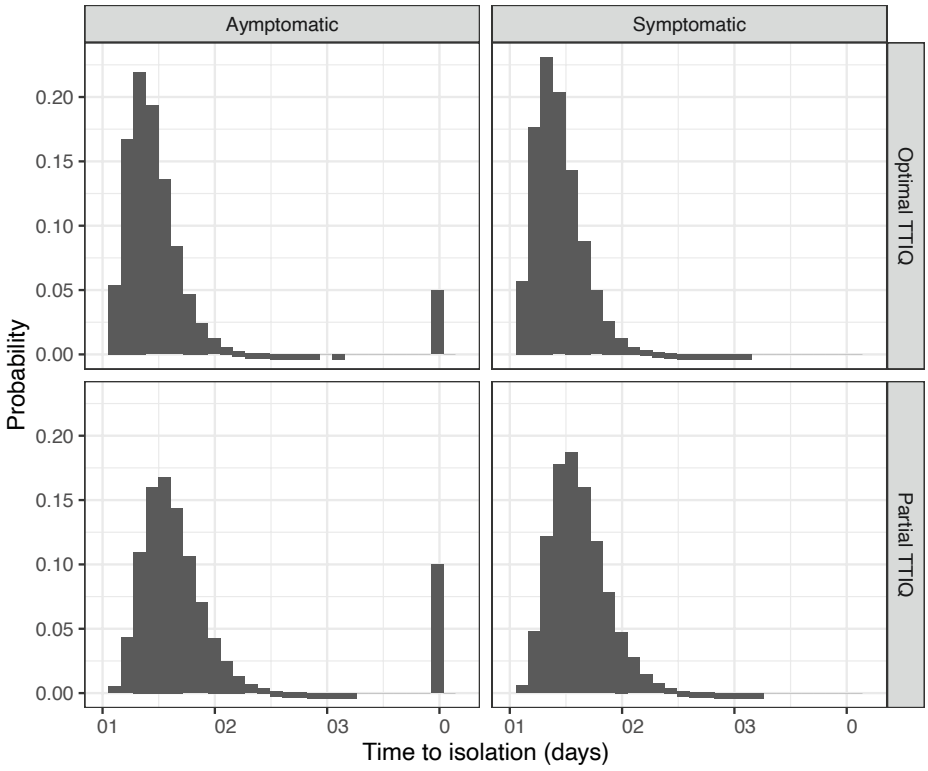

Figure A4: Time to isolation distributions for asymptomatic and symptomatic individuals, under optimal and partial TTIQ. The high probability of "isolation" at 30 days for asymptomatic cases reflects the assumption that some asymptomatic cases are never identified, and therefore recover naturally (and no longer contribute to transmission) at 30 days post-infection.

16. The optimal, symptomatic distribution is gamma(4.35, 1); the partial, symptomatic distribution is gamma(6.15, 1); the optimal, asymptomatic distribution is as for optimal, symptomatic with probability 0.95 and point mass at 30 with probability 0.05; the partial, asymptomatic distribution is as for partial, symptomatic with probability 0.9 and point mass at 30 with probability 0.1.

17. The transition points of 35 cases per day and 100 cases per day averaged over three days, and the average percent reductions are informed by national time-to-isolation data and SA Health TTIQ capacity and expert advice.

Clinical pathways component model

We assumed non-zero age-structured probabilities of hospitalisation (and subsequent ICU admission) for symptomatic COVID-19 cases (Table A4) which were modified by vaccination as detailed above (Table A3)[18]. For simulated cases identified as requiring hospitalisation, we sampled a time to hospitalisation (days) from the gamma distributions provided in Table A5[19]. Patient length of stays in a hospital ward, and possibly subsequently the ICU and post-ICU sections, were similarly sampled from gamma distributions (Table A6)[20]. Probabilities of a patient dying in each of these sections are provided in Table A7, although again these probabilities were modified by the vaccination state of a given patient (Table A3)[21].

Table A4

Age	P(hospitalisation)	P(ICU | hospitalisation)
0-9	0.038	0.1
10-19	0.047	0.13
20-29	0.101	0.1
30-39	0.17	0.12
40-49	0.265	0.28
50-59	0.37	0.28
60-69	0.77	0.31
70-79	0.9	0.2
80+	0.95	0.05

Table A4: Baseline probabilities of hospitalisation and ICU admission (conditioned on symptoms) by age.

18. These estimates were informed by Knock ES, Whittles LK, Lees JA, Perez-Guzman PN, Verity R, FitzJohn RG, Gaythorpe KAM, Imai N, Hinsley W, Okell LC, Rosello A, Kantas N, Walters CE, Bhatia S, Watson OJ, Whittaker C, Cattarino L, Boonyasiri A, Djaafara BA, Fraser K, Fu H, Wang H, Xi X, Donnelly CA, Jauneikaite E, Laydon DJ, White PJ, Ghani AC, Ferguson NM, Cori A, Baguelin M. Key epidemiological drivers and impact of interventions in the 2020 SARS-CoV-2 epidemic in England. Sci Transl Med. 2021 Jul 14;13(602):eabg4262. doi: 10.1126/scitranslmed.abg4262. Epub 2021 Jun 22, and David N. Fisman, Ashleigh R. Tuite Evaluation of the relative virulence of novel SARS-CoV-2 variants: a retrospective cohort study in Ontario, Canada CMAJ Oct 2021, 193 (42) E1619-E1625; DOI: 10.1503/cmaj.211248.

19. These estimates are informed by NSW Health reports.

20. These estimates are based upon Australian and New Zealand data, SA Health expert advice, and Vekaria, B., Overton, C., Wiśniowski, A. et al. Hospital length of stay for COVID-19 patients: Data-driven methods for forward planning. BMC Infect Dis 21, 700 (2021). https://doi.org/10.1186/s12879-021-06371-6.

21. These estimates are informed as per those in Table A4; see footnote 9.

Table A5

Age	Distribution
0-9	gamma(9/0.25, 0.25)
10-19	gamma(8, 1)
20-29	gamma(9/1.5, 1.5)
30-39	gamma(8.5, 1)
40-49	gamma(8.5, 1)
50-59	gamma(8.5, 1)
60-69	gamma(8.5, 1)
70-79	gamma(7, 1)
80+	gamma(5/0.5, 0.5)

Table A5: Distribution of time from symptom onset to hospitalisation by age.

Table A6

Location	Distribution
Ward	1 + gamma(8, 1)
ICU	1 + gamma(6, 2)
Post-ICU Ward	1 + gamma(5/3, 3)

Table A6: Distributions of length of stay in Ward, ICU and Post-ICU Ward.

Table A7

Age	Ward	ICU	Post-ICU
0-9	0.0177	0.1824	0.0338
10-19	0.0163	0.1887	0.0292
20-29	0.0175	0.2028	0.0292
30-39	0.0232	0.2303	0.0322
40-49	0.0414	0.2876	0.0379
50-59	0.0936	0.3681	0.0500
60-69	0.1776	0.4521	0.1007
70-79	0.2938	0.5015	0.2213
80+	0.3711	0.4792	0.3229

Table A7: Baseline probabilities of death given Ward only, or ICU and post-ICU.

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