The impact of re-opening the international border on COVID-19 hospitalisations in Australia: a modelling study

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The known: Current national plans foresee relaxation of international border controls and other restrictions once 80% of people aged 16 years or more (64% of the total population) have been vaccinated against COVID-19.

The new: If Australia re-opens to international travellers while local risk-mitigating restrictions are limited to masks and social distancing, highly disruptive outbreaks will be possible even with 80% vaccination coverage for people aged 16 years or more.

The implications: Population vaccination alone will not be sufficient for suppressing the risk of COVID-19 outbreaks in Australia once international travel is resumed. An ongoing pandemic response will be required of political and health systems throughout 2022.

Abstract

Objective: To estimate the numbers of COVID-19-related hospitalisations in Australia after re-opening the international border.

Design: Population-level deterministic compartmental epidemic modelling of eight scenarios applying various assumptions regarding SARS-CoV-2 transmissibility (baseline R_0 = 3.5 or 7.0), vaccine rollout speed (slow or fast), and scale of border re-opening (mean of 2500 or 13 000 overseas arrivals per day).

Setting: Simulation population size, age structure, and age-based contact rates based on recent estimates for the Australian population. We assumed that 80% vaccination coverage of people aged 16 years or more was reached in mid-October 2021 (fast rollout) or early January 2022 (slow rollout).

Main outcome measures: Numbers of people admitted to hospital with COVID-19, December 2021 – December 2022.

Results: In scenarios assuming a highly transmissible SARS-CoV-2 variant (R_0 = 7.0), opening the international border on either scale was followed by surges in both infections and hospitalisations that would require public health measures beyond mask wearing and social distancing to avoid overwhelming the health system. Reducing the number of hospitalisations to manageable levels required several cycles of additional social and mobility restrictions.

Conclusions: If highly transmissible SARS-CoV-2 variants are circulating locally or overseas, large and disruptive COVID-19 outbreaks will still be possible in Australia after 80% of people aged 16 years or more have been vaccinated. Continuing public health measures to restrict the spread of disease are likely to be necessary throughout 2022.

Following closure of the international border in March 2020, the number of non-Australian citizens entering Australia dropped from more than one million in December 2019 to fewer than 7000 in April 2020.[1] While critical for limiting the entry of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) into Australia at the start of the coronavirus disease 2019 (COVID-19) pandemic,[2] the social and economic costs of the international border closure have had profound impacts in many areas, including tourism, retail trade, and tertiary education.[3]

Population vaccination against COVID-19 is regarded as crucial for re-opening borders.[4] Nearly 25 million COVID-19 vaccine doses had been administered in Australia by late September 2021; 72% of people aged 16 or more had received at least one dose and 47% two doses.[5] We have estimated that 80% total population coverage can be achieved by January 2022, although lags in supply and a considerable level of vaccination hesitancy could delay reaching this target until mid-2022 or later.[6] Achieving high levels of coverage will also require vaccinating children under 12 years of age,[7] the timeline for which depends on the completion of regulatory approval.

To better understand the implications of re-opening the Australian border from December 2021, we modelled disease trajectories, focusing on COVID-19-related hospitalisations, using a population-level epidemic model that also accounts for vaccination rollout and low and high numbers of arrivals from overseas.

Methods

We used a population-level, age-structured deterministic compartmental model to estimate disease trajectories from 1 December 2021 to 31 December 2022 in R 4.0.3 (R Foundation for Statistical Computing), using our *COVOID* package (COVID-19 Open source Infectious Dynamics).[8] Full details of our model assumptions and parameterisation are provided in the online Supporting Information.

We assumed no community SARS-CoV-2 circulation at the starting point of the simulation, and varied three factors: speed of vaccine rollout, scale of border opening, and baseline reproduction number (R_0) in the absence of mitigating interventions (Box 1). Our vaccine rollout projections took the number of available vaccine doses and vaccination hesitancy into account, and predicted two-dose vaccination coverage among eligible adults (people aged 16 years or more) by December 2021 of 91% in the fast and 71% in the slow rollout scenarios (Supporting Information, figure 2). We assumed that all people aged 16 years or more were eligible for vaccination at the start of the simulation period, and that eligibility would be opened to children aged 0–16 years from 1 February 2022. The number of non-Australian arrivals from overseas was set at 2500 or 13 000 per day, corresponding to about 10% or 50% of mean daily arrivals during 2019 (for comparison: a daily mean of 2099 non-Australians arrived in June 2021).[1] Virus transmissibility in the absence of mitigating

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1 Simulated scenarios in which the baseline reproduction number in the absence of mitigating interventions, scale of border opening, and speed of vaccine rollout were varied

Scenario	Reproduction number (R_0)	Daily overseas arrivals from 1 Dec 2021	Vaccine rollout*	Projected vaccine coverage: people aged 16 years or more (all people)	
				1 December 2021	1 February 2022
1	3.5	2500	Slow	71% (56%)	82% (64%)
2	3.5	2500	Fast	91% (71%)	94% (73%)
3	3.5	13 000	Slow	71% (56%)	82% (64%)
4	3.5	13 000	Fast	91% (71%	94% (73%)
5	7.0	2500	Slow	71% (56%)	82% (64%)
6	7.0	2500	Fast	91% (71%)	94% (73%)
7	7.0	13 000	Slow	71% (56%)	82% (64%)
8	7.0	13 000	Fast	91% (71%)	94% (73%)

* See definitions in online Supporting Information, table 4. ◆

interventions was set at R_0 = 3.5 or R_0 = 7.0, respectively approximating values for the Alpha and Delta variants of SARS-CoV-2.

The eight scenarios were modelled from 1 December 2021 to 31 December 2022. All scenarios assumed that some relatively unobtrusive public health measures for limiting virus transmission, such as mask wearing and social distancing, would be retained after borders were opened. In addition, each scenario was repeated with and without tighter responsive restrictions on social contacts that emulated the net effect of school closures, stay-at-home orders, and other measures that limit social contact. These restrictions were activated when the total number of currently infected people exceeded 10 000, and remained in place until the number remained below 2000 for 14 consecutive days. We assumed that the probability of an incoming passenger seeding a new chain of infection was 3.1 per 100 000, based on the estimated failure rate of the Australian hotel quarantine system during 1 April 2020 – 31 January 2021.[9] This may be a conservative estimate, given the higher transmissibility of the Delta variant than of earlier SARS-CoV-2 variants.[10]

Results

For scenarios in which R_0 = 3.5 (ie, similar to that of the SARS-CoV-2 Alpha variant), opening the international border was followed by an increase in local transmission if local restrictions on social contact were limited to mask wearing, social distancing, and similar measures (Supporting Information, figure 3), but the number of people hospitalised with severe COVID-19 was very low (Box 2, A). With greater virus transmissibility (R_0 = 7.0), any opening of the international border combined with limited local social contact restrictions was followed by a major surge in infections (Supporting Information, figure 3) and hospitalisations (Box 2, B).

However, a sharp increase in the number of infections caused by a highly transmissible SARS-CoV-2 variant would prompt additional public health interventions. In our model, the threshold of 10 000 active COVID-19 cases was not reached in scenarios with R_0 = 3.5 (Supporting Information, figure 3). In the higher transmissibility scenarios, several cycles of restrictions (with the aim of reducing social contacts by 70%) would be necessary to manage the risk associated with imported infections once community chains of transmission had been established (Box 2, C).

In all modelled scenarios, we assumed that most people were vaccinated (two doses) for most of the simulation period (Supporting Information, figure 2); consequently, most infections were in people who had been vaccinated (Supporting Information, figure 3). As vaccination protects against severe illness, however, most hospitalisations were of unvaccinated people (Box 2).

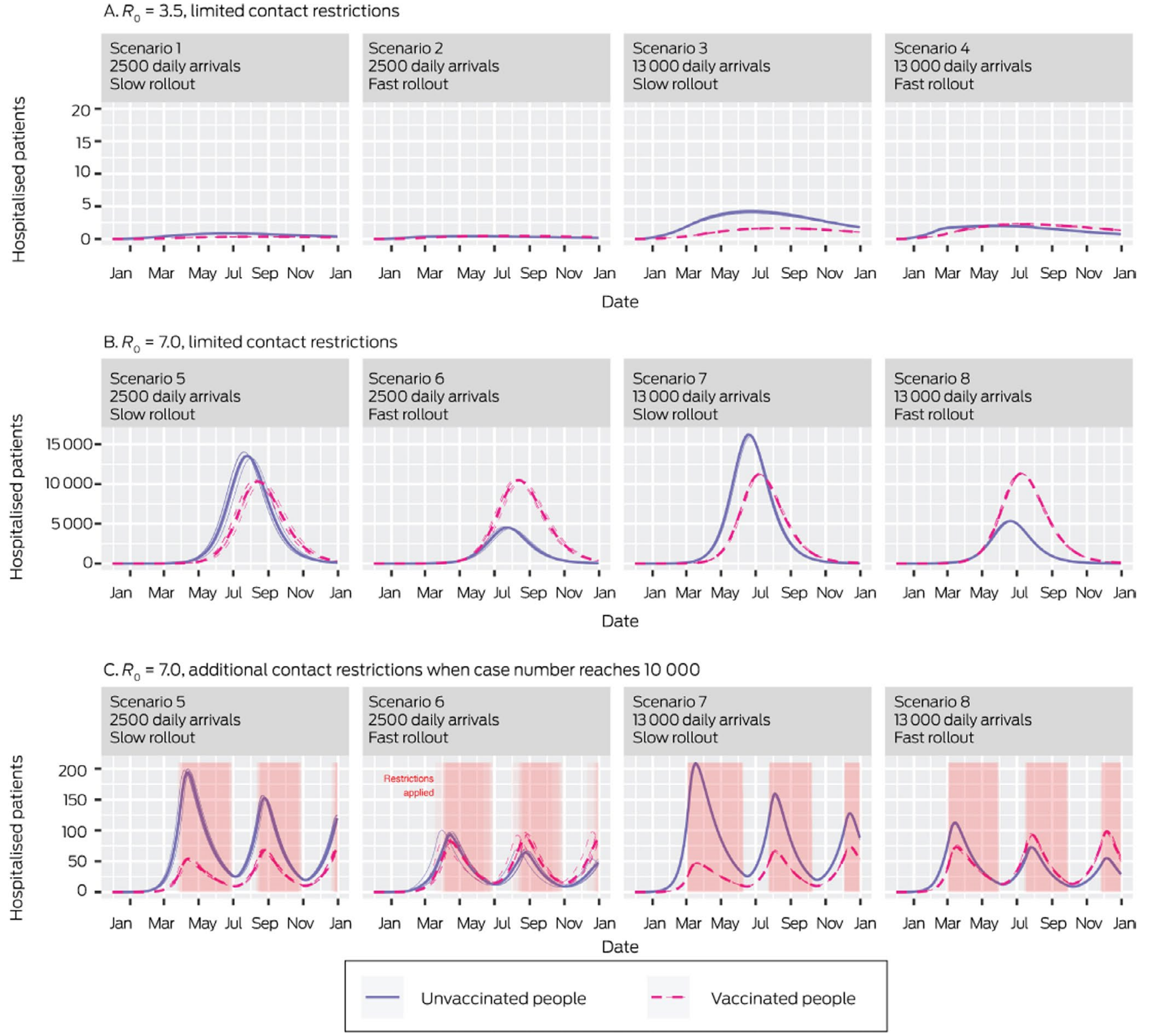
Discussion

Although population vaccination is crucial for reducing COVID-19 case numbers, our modelling indicates that, if the Australian international border is re-opened while highly transmissible SARS-CoV-2 variants are circulating overseas or locally, large and disruptive outbreaks will still be possible after 80% of people aged 16 years or more have received two vaccine doses.

Several modelling studies have recently explored the effects of reducing other public health interventions once specific vaccination coverage levels are achieved.[7,11-15] Despite differing assumptions and methodologies, it has consistently been found that prematurely relaxing social restrictions will result in unacceptably high levels of COVID-19-related illness and death. The level of vaccination coverage required for safely removing restrictions is still being debated. Under the four-phase roadmap for transitioning to managing COVID-19 without restrictions,[4] guided by Doherty Institute modelling,[11] international border controls will be relaxed when 70% of people 16 years of age or older have been vaccinated, and most restrictions will be lifted for vaccinated travellers once 80% are vaccinated. These thresholds correspond to 56% and 64% of the total Australian population, and the models assume that effective testing, tracing, isolation, and quarantine measures will constrain local community transmission of SARS-CoV-2. Modelling by the Grattan Institute is more conservative, indicating that total population vaccination coverage of 80% is the appropriate threshold for removing restrictions and opening the international border should only minimal public health measures be retained (eg, mask wearing on public transport).[12]

We projected that 80% adult population vaccination coverage could be achieved in mid-October 2021 (fast rollout) or early January 2022 (slow rollout). However, the Australian health system will remain at risk of disruptive outbreaks beyond these dates if only minimal social and mobility restrictions are retained. This finding corresponds to the Grattan Institute high

2 Estimated numbers of COVID-19-related hospitalisations (1 December 2021 – 31 December 2022) without responsive restrictions (A, B) and with responsive social restrictions (C*), by viral transmissibility, scale of international border opening, and vaccine rollout speed



COVID-19 = coronavirus disease 2019. * The shaded red bars in panel C mark periods of restrictions on social contacts imposed in response to number of active infections exceeding 10 000. ◆

transmission scenario, which projects a peak of almost 2000 people with COVID-19 requiring intensive care during the ten months after the international border is re-opened. Our conclusions are also consistent with findings that herd protection against COVID-19 will be difficult to achieve in Australia.[13-15] Consequently, mass vaccination will not be the final stage of the Australian pandemic response, especially given the emergence of more transmissible SARS-CoV-2 strains. But as protecting our health system from being overwhelmed has been the priority for public policy, the efficacy of vaccination for averting hospitalisations means that the thresholds for introducing restrictions will increase with vaccination coverage. More efficacious vaccines directed at variants of concern may also become available, further improving the outcomes of mass vaccination.

Maintaining high levels of community testing for SARS-CoV-2, to facilitate rapid detection and isolation of people with new infections, will be essential after 80% vaccination coverage is reached. Public health measures, including mask wearing, may also remain necessary. Quarantine protocols that minimise the risk of viral transmission from travellers into the community and can be adjusted according to the vaccination status and place of origin of individuals will be vital, as will physical infrastructure for effectively quarantining passengers who may be infected with highly transmissible variants. The needs of people in quarantine who need emergency department care[16] and the potential for higher hospitalisation rates with emergent SARS-CoV-2 variants will both require careful health service planning.

Limitations

Our model does not capture the effects of specific policy measures or combinations of measures, such as testing, tracing, isolation, and quarantine, central to the Doherty Institute model.

Instead, the net effect of all possible measures is subsumed under two parameters focused on reducing social contacts and reducing the probability of transmission, applied at the population level. However, effective and targeted testing, tracing, isolation, and quarantine may minimise the need for more disruptive, widespread measures. We did not model the potential waning of vaccine effectiveness, nor the possibility that more efficacious vaccines targeting specific viral variants may become available, but our models can be revised as new data on vaccine effectiveness are published. We employed a population-level deterministic model that does not distinguish individual characteristics beyond broad age group and vaccination status, or recognise social networks beyond age-based contact rates. Nonetheless, it is reassuring that the projections of our computationally less intensive and fully open source model are similar to those of more complex agent-based models.

Conclusion

Political and health system policymakers should not focus exclusively on defining vaccination thresholds at which particular restrictions might be removed. Instead, they should recognise that mass vaccination is unlikely to achieve complete protection against COVID-19, and that health system capacity will still be at risk in the most realistic vaccination coverage scenarios if local chains of transmission are active or the international border is opened while local restrictions on social contact are minimal. The planned re-opening of Australian borders to international travellers increases the risk of introducing new chains of infection and new variants of SARS-CoV-2. Political and health system decision makers should therefore plan an ongoing pandemic response beyond the achievement of population vaccination targets.

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Competing interests: Raina MacIntyre has sat on a Seqirus COVID-19 vaccine advisory board and has consulted or spoken for Janssen and AstraZeneca regarding COVID-19 vaccines. ■

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Supporting Information

Additional Supporting Information is included with the online version of this article.