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Estimating the failure risk of quarantine systems for preventing COVID-19 outbreaks in Australia and New Zealand

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Objectives: To identify COVID-19 outbreaks and border control failures associated with quarantine systems in Australia and New Zealand and to estimate the failure risks.

Design, setting, participants: Observational epidemiological study of travellers transiting quarantine in Australia and New Zealand up to 15 June 2021.

Main outcome measures: The incidence of COVID-19 related failures arising from quarantine, and the failure risk for those transiting quarantine, estimated both per 100,000 travellers and per 1000 SARS-CoV-2 positive cases.

Results: Australia and New Zealand had 32 COVID-19 related failures arising from quarantine systems up to 15 June 2021 (22 and 10, respectively). One resultant outbreak involved an estimated 800 deaths and quarantine failures instigated nine lockdowns. The failure risk for those transiting quarantine was estimated at 5.0 failures per 100,000 travellers and 6.1 failures (95%CI: 4.0 to 8.3) per 1000 SARS-CoV-2 positive cases. The latter risk was two-fold higher in New Zealand compared with Australia.

Conclusions: Quarantine system failures can be costly in terms of lives and economic impacts such as lockdowns. The findings of this study support the need for ongoing improvements to infection controls in quarantine systems in Australia and New Zealand, including through vaccination, or for alternatives to hotel-based quarantine.

The known: Australia and New Zealand have successfully eliminated community transmission of SARS-CoV-2, albeit with occasional outbreaks from imported cases. These countries have primarily used hotel-based quarantine for returning citizens. The quality of this quarantine has improved, but risks of virus transmission within hotels and/or escaping into the community remain high.

The new: Australia and New Zealand had 32 COVID-19 quarantine system failures through 15 June 2021, a risk of 5.0 failures per 100,000 travellers or 6.1 failures per 1000 SARS-CoV-2 positive cases.

The implications: Quarantine systems are facing higher proportions of infected travellers; ongoing monitoring and quality improvements are required.

Introduction

New Zealand and Australian states have successfully eliminated community transmission of the pandemic virus 'severe acute respiratory syndrome coronavirus 2' (SARS-CoV-2),[1] albeit with occasional outbreaks from imported cases that have typically been quickly brought under control. These two countries have primarily used hotel-based quarantine for citizens returning to their countries during the pandemic period, with 14 days of quarantine combined with polymerase chain reaction (PCR) testing and mask use in any shared spaces (eg, common exercise areas used in New Zealand, but not in most Australian states).

Converting hotels for quarantine purposes has the advantage of making use of a resource that would otherwise be underused during a pandemic, given declines in international tourism. However, the major disadvantage of hotel-based quarantine is that it is likely to be less effective than purpose-built quarantine facilities owing to shared spaces and lack of safe ventilation (as per World Health Organization advice on air flow[2]). Moreover, the consequences of leakage of the virus out of quarantine (eg, through facility workers) may be more severe given higher population density in urban settings where the hotels are located. Given these issues, we aimed to estimate the failure risk of quarantine systems in New Zealand and Australia in terms of the spread of 'coronavirus disease 2019' (COVID-19) infection into the community.

As of 13 June 2021, the rolling 7-day average number of COVID-19 vaccine doses administrated per 100 people was 0.46 in Australia and 0.31 in New Zealand.[3] However, this was counted as single vaccine doses and does not equal the total number of people vaccinated (eg, the Pfizer/BioNTech vaccine which is currently used in New Zealand requires two doses).[3] The majority of border workers in Australia and New Zealand have been vaccinated (eg, in New Zealand over 56,000 doses had been administered to border workers as of 28 March 2021,[4] and all hotel quarantine workers in Victoria who have face-to-face contact with returned travellers received their first dose of the vaccine by the first week in April 2021[5]).

Methods

We defined a quarantine system failure as where a border/health worker or person in the community with a link to the quarantine/isolation system, became infected with SARS-CoV-2. This definition included people infected in hospital from cases who had been transferred from a quarantine facility (as such cases were still in the 14-day quarantine process), but did not include pandemic virus transmission between returnees within the quarantine facilities.

We searched official websites in both countries, and for the eight states and territories in Australia, to identify outbreaks and border control failures associated with quarantine systems (searches conducted between 6 January and 23 June 2021). Where an outbreak source was uncertain (eg, the Auckland, New Zealand, August 2020 outbreak) we used the best available evidence to classify it as a quarantine failure or not. The decision to label an incident as a quarantine system failure was confirmed by all co-authors. We used two denominators: a) the estimated number of travellers who went through quarantine facilities during the 2020 year (data were for the period starting 1 April 2020 for Australia and 17 June 2020 for New Zealand) up to 15 June 2021; and b) the number of SARS-CoV-2 positive people who went through these facilities in this same time period. The unit of analyses were New Zealand, the eight Australian states and territories, and both countries combined.

For New Zealand, we used official data on both travellers going through the quarantine system[6] along with official (Ministry of Health) data on SARS-CoV-2 positive cases,[7] although there are some discrepancies in the information about when regular testing began in Managed Isolation and Quarantine (MIQ) facilities. For Australia we used overseas arrival data[8] and health data.[9, 10]

Results

The collated data for quarantine system failures are shown in Table 1, with specific details of each event in the Appendix (Table A1). In Australia, 22 failures were identified, one resultant outbreak caused over 800 deaths (Victoria's second wave) and with eight lockdowns linked to quarantine system failures. In New Zealand, there were ten failures, with one causing an outbreak with three deaths, and also a lockdown.

Given our estimates of the number of travellers processed via quarantine systems (Table 1), the overall risks for both countries combined were one failure per 20,156 travellers, and one failure per 163 SARS-CoV-2 positive cases in quarantine. The combined data can also be interpreted as quarantine system failures leading to a lockdown response per 71,665 travellers; and approximately one death from COVID-19 per 803 travellers (using the 800 deaths estimate from Australia and the three deaths from New Zealand – although this figure is largely driven by the second wave in Victoria and is unlikely generalizable forward in time).

At the country level, there were 10.5 failures per 1000 SARS-CoV-2 positive cases transiting quarantine in New Zealand (95% confidence interval [CI]: 4.0 to 17.0), compared to 5.2 per 1000 SARS-CoV-2 positive cases in Australia (95%CI: 3.0 to 7.3) – a two-fold difference in risk (relative risk: 2.0, 95%CI: 1.0 to 4.2).

Discussion

This analysis identified 32 failures of quarantine systems in Australia and New Zealand combined (up to 15 June 2021). The relatively higher failure risk per 1000 SARS-CoV-2 positive cases transiting quarantine in New Zealand versus Australia could reflect a lower quality approach in the former, with perhaps some of the difference due to greater detection in New Zealand from more border worker testing over a longer period.

These estimates are subject to chance variations due to the low numbers of failures. These estimates will also probably be an underestimate of all quarantine system failures, as not all of those infected will transmit the virus and start a detectable chain of transmission. Genomes of the first 649 viral isolates collected in New Zealand show that only 19% of virus introductions resulted in ongoing transmission of more than one additional case.[11] Therefore, counts of border system failures are sensitive to how they are identified and defined. Indeed, with increased testing (eg, testing of people after leaving quarantine on day 16 as is now common in Australia), we may be detecting failures that previously would have been undetected.

Looking forward, the failure risks per month in New Zealand and Australia may increase, given that the proportion of travellers returning to these countries who are infected is increasing due to global intensification of the pandemic and the increasing infectivity of new SARS-CoV-2 variants.[12] Indeed, there have been several clearly documented cases of spread *within* quarantine hotels (eg, two instances in

Melbourne in February 2021, two instances in Sydney in April 2021, and one in South Australia in May 2021), highlighting the increased risk and evolving situation with more highly infectious variants arriving from overseas.

However, offsetting this trend will be measures such as the vaccination of quarantine workers. In New Zealand, the vaccination of border workers began in February 2021 with the Pfizer/BioNTech vaccine, and as of 11 June 2021 all MIQ workers were fully vaccinated.[13] However, as of 29 June 2021, over 1600 frontline border workers outside of MIQ (eg, those working at ports or as aircrew) were still unvaccinated.[14] A notable limitation of this study was the lack of publicly available data on the vaccination of quarantine workers in Australia. While quarantine workers and other border staff were prioritised for vaccination as part of the first phase of the national vaccine rollout, there was no information available on how many workers had or had not been vaccinated. As of 15 June, only 3% of Australians were fully vaccinated.[15] Some states claimed to have required all border staff to be vaccinated earlier in 2021 (eg, [16, 17]), but investigations of outbreaks in Victoria, Western Australia, Queensland, and New South Wales in June 2021 demonstrated that many border workers, as well as health and aged care workers and residents, had not yet been fully vaccinated.

The full vaccination of frontline border workers could likely have prevented a number of quarantine system failures. However, vaccination does not fully eliminate the risk of contracting SARS-CoV-2, nor does it fully protect against SARS-CoV-2 transmission, although a moderate degree of protection is likely. For example, infection rates were halved for the AstraZeneca vaccine,[18, 19] reduced by 70% for the Moderna mRNA vaccine as indicated by using swab results for asymptomatic infection plus symptomatic cases,[20] and reduced by 95% for the Pfizer/BioNTech mRNA vaccine as indicated by national surveillance data in Israel.[21] For vaccinated people who are infected, primate study evidence suggests (consistent with expectation) that the infectivity is decreased in peak and duration,[22] further protecting the border.

Furthermore, the level of testing of quarantine workers has been increasing (eg,[23]; which will find some failures before they have a chance to establish as an outbreak in the community). There have been other improvements in the quarantine systems over time (eg, improved security, introduction of mask wearing within quarantine settings, reduction in shared spaces, improved personal protective equipment (PPE) used by workers, and other procedures as detailed in both countries[24, 25]).

Another risk reduction practice would be using better or purpose-built facilities in rural locations as these have less risk from close contacts in central business district hotels and within-building spread from poor ventilation systems. To date, there have been no failures at the Howard Springs facility outside of Darwin, and the success of the facility was cited in the announcement in June 2021 of the construction of a new purpose-built quarantine facility in Victoria.[26] Other infection prevention and control measures (eg, PPE) will remain important in all quarantine facilities.

Limitations of our analysis include residual uncertainty around the cause of some outbreaks (eg, the Auckland one in August 2020), and imprecision with denominator data on traveller numbers for Australia (eg, some travellers were moved between states on domestic flights which is not captured in the official data we used). Additionally, case numbers are constantly changing, due to the number of reclassifications caused by false positives and duplications. We also did not assess the change in the quarantine system failures over time due to the relatively small number of failure events. The risk of system failures is

probably highly dynamic on a month-by-month basis as traveller volumes, infection rates, and quarantine processes change, and as vaccination rates among border workers and in the wider community increase.

To substantially reduce the risk of SARS-CoV-2 incursion out of quarantine (until such time as enough of the population is vaccinated), the most obvious action is to reduce arrivals, or even suspend arrivals, from high infection locations (as New Zealand and Australia temporarily did for travel from India and other high risk countries in April 2021[27]). Beyond this, there are a range of other potential improvements in ongoing arrangements and processes as detailed in Table 2. Furthermore, the start of quarantine-free travel between Australia and New Zealand (also known as a "green zone") in April 2021 provides an opportunity to benchmark COVID-19 border control policies and practices, identify potential improvements in both countries, and harmonise best practices across the region. The green zone further intertwines the biosecurity status of both nations and it is therefore even more important to lower the risk of border failures that could disrupt such travel. This shift from a one-size-fits-all strategy to a risk-based approach to border management can be summarised as a 'traffic light' approach.[28]

Conclusions

In summary, Australia and New Zealand have had 32 COVID-19 identified failures arising from quarantine systems up to 15 June 2021. Quarantine system failures can be costly in terms of lives and economic impacts such as lockdowns. Ongoing improvements or alternatives to hotel-based quarantine are required.

Ethics approvals

There was no requirement for ethics review as the study only utilized publicly available anonymized data.

Competing interests

No relevant disclosures.

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Table 1: Identified quarantine system failures in Australia and New Zealand during the COVID-19 pandemic, the relevant denominator populations and estimated failure risks (with numerator and denominator data up to 15 June 2021)

Jurisdiction	Identified quarantine system failures	Travellers experiencing quarantine/ isolation	Active cases of SARS-CoV-2[a] infection identified in quarantine	Failure risk per 100,000 travellers going through quarantine	Failure risk per 1000 positive cases in quarantine (95%CI)[b,*]	Comments
New Zealand	**10**	**145,759**	**955**	**6.9**	**10.5** (4.0 to 17.0)	From 17 June 2020 (date of the first positive test in a quarantine facility) until 15 June 2021, excluding 9 cases with no history of overseas travel. [7]
Australian States and Territories						
Australian Capital Territory (ACT)	0	988	26	0.0	0.0	
Queensland	3	111,805	724	2.7	4.1	Two of the failures occurred at a hospital during the quarantine process.
New South Wales	9	218,457	1,907	4.1	4.7	
Northern Territory	0	16,378	153	0.0	0.0	Includes a non-hotel facility (a former workers' camp) [29]
South Australia	2	20,524	351	9.7	5.7	
Tasmania	0	1,287	21	0.0	0.0	
Victoria	5	83,904	550	6.0	9.1	Victoria suspended flights from 14 February to 25 March 2021 due to the Holiday Inn cluster, where a nebuliser allegedly caused a quarantine failure and resulted in 22 cases. Victoria also suspended flights and the entire hotel quarantine system during the second wave between 2 July and 6 December 2020.
Western Australia	3	45,880	519	6.5	5.8	
All of Australia	**22**	**499,223**	**4,251**	**4.4**	**5.2** (3.0 to 7.3)	These only included cases diagnosed between 1 April 2020 until 15 June 2021.
			Relative risk (New Zealand : Australia)		**2.0** (1.0 to 4.2)	P-value = 0.0793 (Mid-P exact, 2-tailed test)
New Zealand and Australia						
Both countries combined	**32**	**644,982**	**5,206**	**5.0**	**6.1** (4.0 to 8.3)	

[a] SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

[b] 95%CI: 95% confidence interval

* 95% confidence intervals are shown in parentheses for country-level risks only; state-level risks with zeros or low numbers are too sparse.

Table 2: List of potential policy and operational options for improved COVID-19 control associated with quarantine systems in Australia and New Zealand, including measures to reduce the numbers of infected people arriving into quarantine facilities

Policy option	Description	Our priority rankings
1. Cap travel from high prevalence countries and/or suspend for a period	Reduce the in-flow of travellers by reducing or suspending flights to Australia and NZ[a] from very high incidence countries where the pandemic is out of control. These governments have the legal powers to put conditions on the existing rights of their citizens to enter their country of citizenship (ie, on public health grounds).	Top priority
2. Pre-departure testing plus/minus pre-departure quarantine	Expand existing requirements for pre-departure testing to additional traveller source countries. Pre-departure testing could be expanded from not only a PCR[b] test within 72 hours of departure to also add a rapid test at the airport immediately before departure (given many infected may have started shedding the virus in the previous 72 hours and most, but not all, of such cases will be detected by a rapid test even though it has lower sensitivity). Of note is that such arrangements are considered legally acceptable (see the above row). Pre-departure quarantine (eg, for a week), would provide additional assurance, but this would probably need to be in a transport hub (eg, at an airport hotel at Singapore or Hawaii) where NZ and Australian officials were permitted access to ensure quality processes. Even if establishing a formal facility is shown to be impractical, all incoming travellers could be asked to self-quarantine as strictly as possible in the week before travel, eg, by a request through the passenger booking system (see Policy Option 4).	Top priority
3. Pre-departure vaccination	Make travel contingent on completing a course of approved vaccination. This measure assumes the vaccine is at least partially effective at preventing transmission. This requirement needs further investigation and development.	Uncertain
4. Use passenger booking systems to reduce infection risk	Require passengers to declare pre-departure COVID-19[c] precautions via the system that they use to book spaces in quarantine facilities prior to travel. Such a system is operating in NZ and could be adopted more widely in Australia.	High priority
5. Increase in-flight precautions	Explore means to reduce the risk of in-flight infection as documented on a flight to NZ.[30] This could be via more stringent enforcement of mask wearing in airports and on flights, and the use of higher-efficacy masks (although fit can be critical to the level of protection offered by some masks and respirators) and/or double masking. An experimental study conducted by researchers at the US CDC[d] found that a medical procedure mask alone blocked 56.1% of particles from a simulated cough, and a cloth mask alone blocked 51.4%, while the combination of a cloth mask covering a medical procedure mask (double masking) blocked 85.4% of cough particles.[31] In a second experiment, double masking of the source dummy (which produced simulated cough particles) reduced the cumulative exposure of an unmasked receiver dummy by 82.2%, and when the source was unmasked and the receiver was fitted with a double mask, the receiver's cumulative exposure was reduced by 83.0%.[31] When both the source and the receiver were double masked, the cumulative exposure of the receiver was reduced by 96.4%.[26] Another laboratory-based study that used humans rather than dummies to compare the FFE[e] of commonly available masks worn singly, doubled, or in combination found that on average, across all masks and volunteers, adding a second medical procedure mask improved mean FFE from 55% when single masking to 66% when double masking.[32] Specifically, wearing a procedure mask under a cloth face covering produced the largest improvement in overall FFE (from 66% to 81%).[32] The improvement in FFE was likely due to the reduction of leaks between the mask and skin.[32]	High priority

Policy option	Description	Our priority rankings
	While the findings of these studies may not be representative of double masking in real world settings, they suggest the potential for both improved source control (ie, reduced exposure from infected wearers) and reduced wearer exposure (ie, reduced exposure of uninfected wearers). Minimizing talking when masks are displaced during eating and drinking, and improved ventilation and spacing requirements on flights might also be worthwhile.	
6. Reduce infection risk at airports and transit hubs	Ensure measures are in place at departure airports and transit hubs to minimize the risk of cross infection (eg, through physical distancing and mask use).	Medium priority
7. Improve local transport arrangements	Ensure sufficient physical distancing of travellers on arrival and in transit to quarantine (eg, lowering density on buses). For such arrangements, higher efficacy masks or double masking could be required (see "5. Increase in in-flight precautions" above).	Medium priority
8. Shift to discrete quarantine units	Shift some or all quarantine facilities to rural military bases or camps where discrete units (eg, mobile homes or caravans) could be appropriately spatially separated. The success (to date – see Table A1 in the Appendix) of the Howard Springs facility (a converted workers' camp[29]) should be considered. This approach allows for natural ventilation and eliminates shared indoor spaces. If spaces were limited, then these settings could be used for travellers from the highest risk countries.	High priority
9. Restrict hotel quarantine in large cities to low-risk travellers	Reserve hotel quarantine in large cities to the lowest risk category of travellers, with hotels in more minor cities being used for the highest risk category of travellers. However, the risk/benefit analysis of such changes would need to consider airport access and if the additional travelling to minor cities poses excessive additional risk.	High priority
10. Expand use of PCR testing of saliva in facility workers (and travellers)	Expand the regular (daily) use of PCR testing of saliva of facility workers to all facilities in both countries. This approach could also be considered for all travellers, albeit potentially still combined with existing testing regimens. In view of increased transmissibility of new variants, consideration should be given to testing of all workers in border-associated occupations (eg, providing airline meals and laundry services) at least twice per week. Documented negative tests at appropriate frequency should be an occupational requirement for all border workers instead of the self-report systems (as currently used in NZ and Australia).	High priority
11. Accelerate or mandate vaccination for quarantine staff	Vaccinate all quarantine workers against COVID-19 and redeploy all unvaccinated workers from the front line. This measure will be particularly valuable when vaccines are known to prevent transmission in addition to protecting recipients from illness.	As of April 2021, this measure was nearing completion in some jurisdictions
12. Cohorting complete flights of travellers	Cohorting of flights means that all returnees arriving into a country go to the same quarantine facility until that facility is full and then the intake switches to another facility and so on. This approach is designed to reduce cross-infection in such facilities. This system was introduced in NZ on 16 May 2021.	Medium priority
13. Upgrade processes at quarantine facilities	Upgrade processes at quarantine facilities in terms of eliminating shared spaces (eg, no shared exercise areas and shared smoking areas), in particular ensuring that day cohorts do not mix under any circumstances. Ventilation improvements could also be considered with limiting the use of rooms to only those with external windows or a balcony.	Medium priority
14. Prosecute rule breaking in quarantine facilities	Enforce quarantine facility rules more rigorously. Rule breaking, which is relatively common in NZ facilities,[33] could start to be prosecuted (given no prosecutions during 2020).	Medium priority

Policy option	Description	Our priority rankings
15. Improve conditions for quarantine staff	Improve working conditions for the staff in quarantine facilities to minimize the risk of overwork (which may increase the risk of PPE failures) or of workers taking on other part-time jobs in other settings. For example, in February 2021 there were still concerns by NZ health workers about staffing inadequacies in these facilities. Some states in Australia have banned front-line quarantine staff from working second jobs.	High priority
16. Improve management of travellers who smoke	Introduce specific measures for travellers who are nicotine dependent to reduce their need to smoke in designated areas during their travel and while in managed quarantine (eg, nicotine replacement treatment as a requirement for travel).	Medium priority
17. Add post-quarantine control measures	Introduce a post-quarantine period of home-quarantine to reduce the risk of local transmission arising from undetected infections in people leaving hotel quarantine facilities (which may arise from either exceptionally long incubation periods or cross infection during quarantine stays). Post-quarantine testing could also be used to detect such infections.	Medium priority
18. Mandate the use of digital contact tracing tools	Mandate quarantine workers to use digital technologies (eg, the Bluetooth function on the COVID Tracer smartphone apps) to facilitate contact tracing in the event of a border failure. Travellers could be required to use such technologies for two weeks after completing their time in quarantine. There is also a case for travellers using these tools within quarantine as (at least in NZ) quarantine facilities are sometimes evacuated for fire alarms and burst water pipes.	Medium priority

[a] NZ: New Zealand
[b] PCR: polymerase chain reaction
[c] COVID-19: coronavirus disease 2019
[d] US CDC: United States Centers for Disease Control and Prevention
[e] FFE: fitted filtration efficiency

Appendix for: Estimating the Failure Risk of Quarantine Systems for Preventing COVID-19 Outbreaks in Australia and New Zealand

Appendix Table A1: List of COVID-19 border control failures associated with quarantine systems in Australia and New Zealand during 2020 and up to 15 June 2021

Event	Extent of known spread	Details
Australia		
Rydges Hotel – Victoria "second wave" outbreak (late May to late October 2020)	Over 19,800 cases,[1, 2] and over 800 deaths[3]	Genomic testing indicated that 99% of Victoria's second wave of community COVID-19[a] cases were linked to transmission events related to returned travellers infecting workers at the Rydges Hotel in Carlton and the Stamford Plaza Hotel (see row below) in Melbourne's CBD[b], which were used as facilities for quarantine.[4] Specifically, around 90% of cases can be traced back to a single family of four that returned to Australia in mid-May and were quarantined at the Rydges Hotel.[5] The virus then spread from the infected workers to the community, with high rates of local transmission.[4] The outbreak led to a stringent lockdown for 112 days in the state, with particularly strict measures in the major city of Melbourne.[6] At least nine people employed in Melbourne's hotel quarantine program tested positive between late July and early October 2020, although the cases may have been a reflection of substantial community transmission in Melbourne at the time rather than additional hotel quarantine failures.[7] Two of those cases worked while infectious.[7]
Stamford Plaza Hotel - Victoria "second wave" outbreak (late May to late October 2020)	See row above	Almost 10% of cases in Victoria's "second wave" outbreak were attributable to an outbreak at the Stamford Hotel in mid-June.[4] The outbreak was traced back to international travellers who returned to Australia in early June,[4] and then was spread by security guards who worked at the facility.[8]
Marriot Hotel at Circular Quay in Sydney, NSW[h] (August 2020)	2 security guards	A security guard at the Marriot Hotel at Circular Quay in Sydney tested positive for COVID-19 on 15 August.[9] Genomic sequencing linked the infection to a returned overseas traveller at the facility.[9] A second security guard subsequently tested positive.[10]
Parafield outbreak in South Australia (December 2020)	33 cases[3]	Genomic testing indicated that Adelaide's Parafield cluster was linked to transmission events related to a returned traveller in a quarantine hotel infecting workers in the facility, possibly due to poor ventilation at the facility.[4] The virus spread from the workers to the community, resulting in a strict lockdown.[4]
Quarantine hotel facility cleaner infected in Sydney,	A single worker	A quarantine hotel worker (a cleaner) who completed shifts at two quarantine hotels, the Ibis Hotel and the Novotel in Darling Harbour in Sydney, tested positive in early December.[11] There

Event	Extent of known spread	Details
NSW (December 2020)		was also spread in a facility with 5 returned travellers being infected.
Airport Bus Driver NSW (December 2020)	A single worker	A Sydney van driver who drives international flight crew to and from Sydney Airport, tested positive for COVID-19 on 17 December 2021.[12] Although he was symptomatic and worked for 3 days before being tested, this did not cause an outbreak and it was contained to one case.[12]
Avalon outbreak in NSW (January 2021)	151 cases (as of 11 January 2021)[13]	It has been reported that genomic sequencing suggests that the strain is of US origin and entered Australia via an infectious returned traveller who entered hotel quarantine upon arrival.[11] It is currently unknown how the virus spread to the community and source investigations were still underway (as per January 2021). Case numbers include those from the linked Croydon and Wollongong clusters, but not the linked Black Rock cluster in Victoria (27 cases as of 5 January 2021) due to separate reporting by states.
Berala outbreak in NSW (January 2021)	26 cases (as of 11 January 2021)[13]	It has been reported that genomic sequencing linked the outbreak back to infectious international travellers.[14] A patient transport worker transferred infectious travellers from Sydney Airport to a hospital.[13, 14] Another patient transport worker who was a close contact of the first then also tested positive.[13, 14] The virus then spread from the second infected worker into the community, seeding the Berala outbreak.[14]
Hotel Grand Chancellor outbreak in Brisbane, Queensland (January 2021)	6 cases (as of 13 January 2021)[15]	A hotel quarantine worker in Brisbane tested positive in early January 2021 for the Alpha variant of COVID-19.[16] This case led to a three-day lockdown in the greater Brisbane area, while contact tracers worked to ensure there was no community transmission of the strain.[17] It was later revealed that there were six genomically linked cases within the quarantine facility, including the hotel quarantine worker and five returned travellers.[15]
Four Points by Sheraton hotel, Western Australia (January 2021)	A single worker	A Perth quarantine hotel security guard, who worked a second job as a ride share driver, tested positive to the UK strain of SARS-CoV-2[c], sparking a five-day lockdown for 80 per cent of the state's population, in an attempt to stop any further transmission.[18] It's believed he was exposed to the virus on the 26 January when he worked at Four Points by Sheraton, on the same floor where a quarantined returned traveller with a confirmed case of infection with the Alpha variant, was staying. After feeling sick on 28 January, the case visited a GP[d], and tested positive on 30 January. The exact cause is unknown, but it's believed poor ventilation could be a factor.[19] This comes a week after Western Australia committed to daily testing of the hotel quarantine staff, instead of weekly.[20] Quarantine hotel staff, including cleaners, security guards and catering staff, are no longer allowed to have

Event	Extent of known spread	Details
		second jobs but will receive a pay increase of about 40 per cent as compensation.[18] It has been announced an inquiry will be held.[19]
Grand Hyatt Hotel, Victoria (February 2021)	A single worker	One 26-year-old staff member at the Grand Hyatt Hotel (an isolation facility that was used for players and support staff for the Australian Open) tested positive for a highly transmissible variant of COVID-19 (ie, the B.1.1.7 or Alpha variant) in February 2021, leading to heightened restrictions.[21] The close contacts of the case all tested negative, and the outbreak did not spread into the wider community.[21]
Holiday Inn Hotel Cluster, Victoria (February 2021)	22 cases	Twenty-two cases have been linked to the Holiday Inn cluster in Melbourne, where an infected returned traveller used a nebuliser, causing an outbreak and a 5-day lockdown.[22] There were no further cases detected in the community during the lockdown as all confirmed cases had already been informed of their status as close contacts and were in isolation for the duration of their infectious period. Cases included returned travellers, hotel quarantine staff and their families, as well as a Melbourne Airport worker.[22]
Princess Alexandra Hospital Doctor outbreak, Brisbane, Queensland (March 2021)	6 cases[23]	A doctor and a nurse (see row below) who worked at the Princess Alexandra Hospital while unvaccinated were linked to two separate COVID-19 outbreaks.[23] While both outbreaks were the highly transmissible Alpha variant of the disease and originated at the same hospital, they were from two different sources.[23] The doctor tested positive on 12 March 2021, with subsequent infections in 5 other persons.[23] These outbreaks resulted in a 3-day lockdown just before the Easter holiday.[23]
Princess Alexandra Hospital Nurse outbreak, Brisbane, Queensland (March 2021)	13 cases[24]	A nurse (see row above) who worked on a COVID-19 ward at the Princess Alexandra Hospital while unvaccinated tested positive in late March.[23] Genome sequencing links the case to an overseas traveller from India who was being cared for at the hospital.[25] The nurse's sister, a number of attendees at a “hen's party”, and several other contacts were subsequently infected.[23]
Sofitel Wentworth in Sydney, NSW (March 2021)	A single security guard	A security guard at the Sofitel Wentworth in Sydney tested positive for COVID-19 on 13 March through routine surveillance testing.[26] Genomic sequencing linked the case to a returned traveller and subsequent testing revealed that another returned traveller was also infected within the facility.[26]
Mercure Hotel Cluster in Perth, Western Australia (April 2021)	3 cases	A mother and her four-year-old daughter who had returned from the UK, and a traveller who had returned from China contracted the virus while in hotel quarantine.[27] The mother and child's infections were detected on 16 April and genomically linked to a couple who had returned from India on April 10 and subsequently tested positive for the Alpha variant.[27] All of the travellers were

Event	Extent of known spread	Details
		staying in adjacent rooms on the same hotel floor.[27] The returned traveller from China tested negative on release from hotel quarantine in Perth on 17 April, but later tested positive for COVID-19 in Melbourne.[28] The case then spent up to five days in the community in Perth while infectious, and two linked community cases were identified.[29] The outbreak led to a 3 day lockdown in Perth and the neighbouring Peel region,[28] and a brief suspension in quarantine-free travel between Western Australia and NZ.[29] The ventilation at the Mercure hotel had previously been identified as the riskiest among Western Australia's 10 quarantine hotels, with an engineer finding that the corridors had no independent airflow with oxygen supply leaking from the adjoining rooms.[27] Chief Health Officer Andy Robertson had recommended that the Mercure Hotel no longer operate as a quarantine facility on 14 April.[27]
Community cases in NSW (May 2021)	2 known cases (possibly more)	On 5 May 2021, a man in his 50s from Sydney was diagnosed with COVID-19.[30] His wife subsequently tested positive.[30] The cases were genomically linked to a traveller who returned from the US and was moved to a quarantine facility on 28 April.[31] However, an epidemiological link between the traveller and the cases has yet to be established,[30] suggesting that there may be additional cases in the community. Additionally, fragments of coronavirus were detected in wastewater samples in Sydney.[31] The cases did not result in a lockdown in NSW, but additional restrictions, including compulsory masking and limits on indoor gatherings were put in place.[30] Additionally, the situation led the NZ Government to temporarily pause their quarantine-free travel arrangement with NSW for 48 hours, and a close contact of one of the cases was placed in a MIQ facility in Christchurch after travelling to NZ.[30]
Pan Pacific Hotel in Perth, Western Australia (May 2021)	3 cases	A security guard at the Pan Pacific Hotel in Perth tested positive on 1 May.[32] He worked on the same floor as two infected travellers (one from the US and one from Indonesia).[32] He had had the first Pfizer vaccination, but not the second.[32] Two of the seven people that he lived with subsequently tested positive.[32] This was an event for which Western Australia was still subject to restrictions from a previous outbreak.[32]
Whittlesea Community Outbreak in Victoria, stemming from the Playford Hotel in South Australia (May 2021)	At least 63 cases (outbreak was still active as of 23 June 2021)	A traveller who returned from India via the Maldives and Singapore completed the required stay in quarantine in South Australia.[33] After leaving quarantine on 4 May, he then travelled directly to his home in Victoria. He subsequently developed symptoms and tested positive.[33] It is thought that the traveller likely contracted the virus while in quarantine in South Australia; it has been reported that the traveller stayed next door to another person who tested positive for the virus.[33] This later caused a

Event	Extent of known spread	Details
		widespread outbreak, leaking into aged care, and resulted in a 14-day lockdown followed by tight restrictions.[34]
West Melbourne Delta Variant Cluster, Victoria (May 2021)	15 known cases (possibly more)	This outbreak has been genomically linked to a hotel quarantine case that arrived in Victoria from Sri Lanka on 8 May 2021 and tested positive on the same day.[35] The case was subsequently moved from the Novotel Ibis quarantine hotel in Melbourne's CBD to the Holiday Inn on 9 May, and then was released from quarantine on 23 May 2021.[35] The variant was then detected in members of a family in Victoria that were known to have travelled to parts of NSW, and had the same genomic sequence as the hotel quarantine case.[35] However, there is still uncertainty about the link between these cases, as no formal epidemiological link has been established, suggesting that there may have been additional cases in the community.[35]
Airport Limo Driver in NSW (June 2021)	1 case (outbreak was still active as of 23 June 2021)	A 60-year-old airport limo driver, who was involved in transporting international flight crew to and from Sydney Airport, tested positive for COVID-19 on 15 June.[36] It's believed he transported a crew of three from a FedEx freight plane before he became infectious, on 11 June.[36] This is currently being investigated, as authorities believe this man breached NSW quarantine and testing protocols.[36]
New Zealand		
Auckland outbreak (August 2020)	A total of 179 cases, with 3 deaths [37]	The cause of this outbreak remains unknown, but genomic work probably provides the best evidence to this being a border facility (isolation or quarantine facility) failure: "There are a large number of similar genomes which are from the UK[e], which would seem to suggest the UK is the most likely source of any unknown importation".[38] This was at a time when 40% of cases in NZ quarantine/isolation facilities did not have genomic work on the virus infecting them (ie, there was not enough complete virus in the samples). It was also estimated[38] that there was only a very tiny risk of this outbreak being a continuation of the March/April spread of the pandemic in NZ: "Our Bayesian phylogenetic analysis … estimates that there is a 0.4% probability that case 20VR2563 is in the "sister clade"' of the Auckland cluster." Finally, the chance of the outbreak being from contaminated imported food was also considered very unlikely: "Our Bayesian phylogenetic analysis … shows that the estimated mutation rate on the branch leading to the cluster is not a lot smaller than elsewhere in the tree, lending little weight to the possibility that the virus lay dormant on packing material for a long period of time."
Border facility maintenance worker	A single worker	A shared lift environment in a quarantine hotel (the Rydges Hotel in Central Auckland) was the source suspected by officials,[39] with the sharing being only minutes apart.[38] The genomic sequencing

Event	Extent of known spread	Details
infected (August 2020)		indicated the same virus infecting the worker as per a recent traveller in the same facility.[38]
Border facility health worker infected (September 2020)	A single worker	This was a work-related infection associated with a hotel facility used for isolating infected cases (the Jet Park Hotel, Auckland), given that the case was linked via genomic sequencing to 3 cases within the facility.[40] Some details of the full investigation report were provided to the media and these suggested that while the nurse wore PPE[f], there was a period where the associated patient did not have a mask on during treatment.[41] This situation could have contributed to a failure of the PPE worn by the nurse.
Traveller-related outbreak / Crowne Plaza, Christchurch border facility (September 2020)	The 2 returnees and 4 others	Three returnees (Cases A, B, and C) tested positive for SARS-CoV-2 while in an MIQ facility (ie, these cases were caught at the border).[42] Evidence suggests that two returnees (Cases D and E) were then infected through suspended aerosol particles while in the same hotel quarantine facility (Cases D and E were staying in the room next to Case C), before then moving into the community.[42, 43] These infected returnees appear to have then infected another person (Case G), potentially on a charter flight after leaving the facility.[42, 43] A household contact of Cases D and E was also infected (Case F).[42, 44] Two household contacts of Case G were also infected.[42]
Border facility health worker (Case A) in Christchurch (Nove mber 2020)	A single worker	This was a work-related infection associated with a facility used for isolating infected cases. Both this case (and "Case B" below) had the virus genome sequencing linked to infection in a group of international mariners in the same hotel facility but with different virus subtypes in each case.[39] "The finding supports the current theory that there were two separate events infecting both workers at the facility." These cases of infected health workers appear to have contributed to border control nurses threatening strike action if they were not supplied with improved PPE. One estimate was that 12 of the mariners were infected on arrival in NZ, but with subsequent spread within the facility a total of 31 mariners were ultimately infected.[45]
Another border facility health worker (Case B) (see above)	A single worker	This was a separate work-related infection associated with a border control facility – see in the row above.
Defence Force worker outbreak (November 2020)	The worker, a co-worker and 4 others (total of 6 cases)	This was a work-related infection in a Defence Force worker associated with a hotel border facility in Auckland (used for isolating known infected cases). "The genome sequencing we have conducted on Case A's test result shows a direct link to two travellers who are part of a family group in the quarantine facility".[46] The route of transmission to one of the community cases remains a mystery (albeit they worked in the same locality within Auckland City). Associated with these cases, the Prime

Event	Extent of known spread	Details
		Minister made statements around the need for further risk reduction.[47]
Traveller infectious after leaving a quarantine facility (January 2021)	1 traveller	A traveller was identified as being infectious in the community after leaving a quarantine facility (Pullman, Auckland). The traveller reportedly had the Beta variant (lineage B.1.351) of the pandemic virus.[48] Genome sequencing has linked this case to another traveller who was in the same facility.[49] The transmission mechanism has not been precisely identified with investigations still proceeding as of mid-February 2021. However, officials consider it likely to have been a separate transmission event to the one in the following row.
Travelers infectious after leaving a quarantine facility (January 2021)	2 travellers and a contact	Two travellers (a parent and child) were identified as infectious in the community after being infected with the Beta variant of the pandemic virus, with a link to a quarantine facility (Pullman, Auckland).[50] A close contact (the mother of the child) also became infected.[51] The transmission mechanism has not been precisely identified with investigations still proceeding as of mid-February 2021.
MIQ[g] workers (March 2021)	3 workers	A cleaner at the Grand Millennium Hotel MIQ facility in Auckland (Case A) tested positive during routine surveillance testing on 22 March 2021.[52] While a household contact returned a weak positive the next day,[53] subsequent tests were negative.[54] The MIQ worker had recently been vaccinated (with the Pfizer/BioNTech vaccine) on 23 February, with a second dose on 16 March,[53] although they tested positive before full protection from the vaccine could be expected. Their family had not yet been vaccinated.[53] Genome sequencing revealed that Case A was infected with a highly transmissible variant (Alpha) and was linked to a traveller in the facility who had arrived on 13 March.[55] In early April, two unvaccinated security guards at the same facility tested positive (Cases B and C) and genome sequencing linked the two cases to Case A.[56, 57]

[a] COVID-19: coronavirus disease 2019
[b] CBD: central business district
[c] SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
[d] GP: general practitioner
[e] UK: United Kingdom
[f] PPE: personal protective equipment
[g] MIQ: managed isolation and quarantine
[h] NSW: New South Wales

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