COVID-19 outbreaks in Aotearoa New Zealand: urgent action is required to address systematic causes and consequences of border failures

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ABSTRACT

Between August and November 2020, Aotearoa New Zealand experienced eight known failures of the COVID-19 border control system. Multiple introductions of this highly transmissible virus into New Zealand's almost completely susceptible population present a high risk of uncontrollable spread, threatening New Zealand's elimination strategy. In this editorial, we propose that, although steps are being taken reactively in response to these known breaches, systematic underestimation of risk across the pandemic response makes future failures inevitable. We present an epidemiological framework for identifying and addressing risk, giving examples of actions that can be taken to reduce the probability of further outbreaks and enable New Zealand to benefit from sustained elimination of COVID-19.

By May 2020, Aotearoa New Zealand had successfully eliminated community transmission of SARS-CoV-2 (COVID-19).[1] The only remaining source of new infections in this island nation was then by introduction through the border.[2] Managing COVID-19 transmission risk from the large numbers of returning New Zealand citizens, permanent residents and government-approved visitors has placed enormous demands on staff and systems. Although the vast majority of returning travellers have made a safe transit through the borders into their communities, system failures can and do occur.

Lapses in border security during Alert Levels 3 and 4 could not develop into sustained outbreaks, because the whole country was effectively in quarantine. But when the country returned to Alert Level 1 the risk of rapid community transmission returned. Since that initial return, the country has experienced eight occurrences of transmission to individuals outside managed isolation and quarantine (MIQ) facilities. The circumstances surrounding these high-risk events (as far as they are known) are detailed in a recent Public Health Expert blog.[3] Since publication of the blog, an additional instance of community transmission has been identified in the Defence Force worker (November) outbreak (Case F).

These known recent outbreaks have been swiftly controlled using a well-coordinated public health response supported with innovative and effective use of genomic sequencing. However, each undetected introduction of the SARS-CoV-2 virus into community spaces is an extremely high-risk

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event, as illustrated by the Auckland August outbreak, New Zealand's largest to date. The origin of the index community transmission occurrence in that outbreak remains unknown as the outbreak only became visible after it was already well-established and difficult to control, and the outbreak reached 179 cases before transmission was extinguished.

COVID-19 outbreaks in Aotearoa have caused significant morbidity (including chronic severe morbidity—the 'Long COVID' syndromes) and, sadly, also fatal cases.[4] Community transmission that requires stepping up Alert Levels is highly disruptive, with consequences that include widespread hardship from loss of employment, increased mental distress, reduction in economic activity and both educational and non-educational harms to children and young people from school closures.

The COVID-19 pandemic has some characteristics that lead to a systematic underestimation of risk. We propose using the well-established epidemiological concept of false negative test results to bridge this gap and identify the key areas where additional control measures will make the most difference.

Understanding systematic border failures as a problem of false negative results

Health professionals are familiar with the concept of false negative diagnostic test results, where a true positive is erroneously identified as a negative or missed case. This situation results in lost opportunities to manage a case appropriately. In an infectious disease outbreak, this type of error also means that individuals will be unaware of the risk they pose to others.

The proportion of false negative results is a function of the sensitivity of the test (ie, the proportion of true positives testing positive).[5] Thus, because no test is perfect, a negative COVID-19 result does not rule out infection: it only means that the person is less likely to be a case than if they had tested positive. What this means in practice is that the risk of being falsely reassured by a test depends on two factors:

1. the person's chance of being infected based on their circumstances (the 'pre-test probability')
2. the test sensitivity or, equivalently, the false negative risk[6]; the latter appears more appropriate for a risk assessment format.

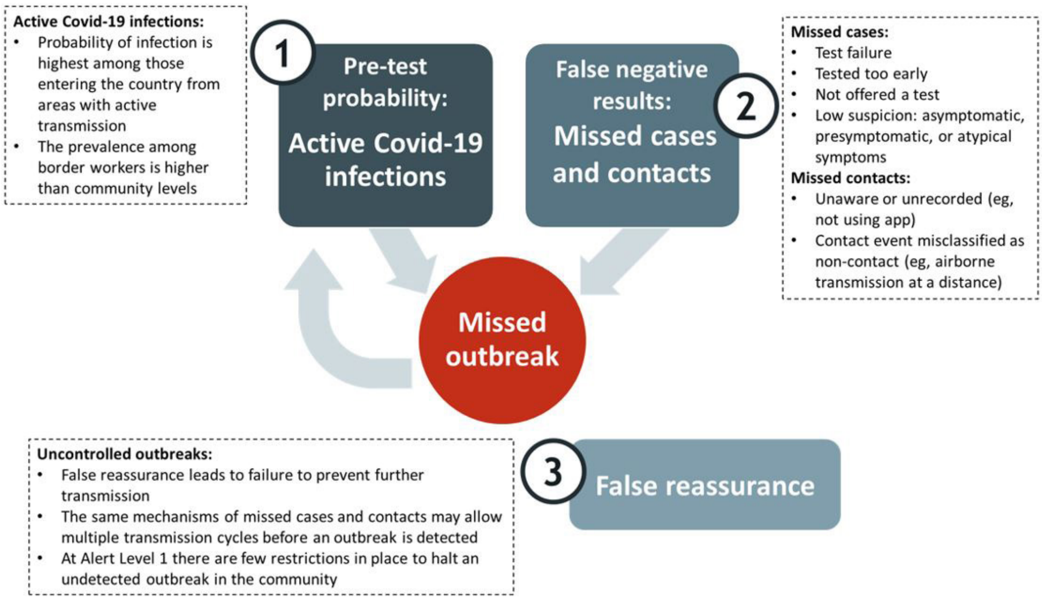
A key strategy in using this approach for a systematic assessment of risk in the border system is to think about COVID-19 testing beyond the narrow sense of diagnostic testing in individuals[7] (eg, using the RT-PCR test) and instead consider case finding as a COVID-19 test of the border system and the country as a whole. In that context, a 'positive test result' indicates detection of COVID-19 transmission from border settings into the community, while a 'false negative' is a missed transmission.

There are indications that the border system may be experiencing many false negative results in addition to the known positives. Genomic sequencing of imported cases during the first pandemic phase in 2020 demonstrated that only 19% of introduced sequences resulted in onward transmission of more than one case.[8] This phenomenon has also been described outside New Zealand and is known as overdispersion. The converse of this observation is that the number of true introductions of COVID-19 into communities is likely to be larger (and may be much larger) than the number of observed outbreaks.

How false negatives drive border failures: areas for intervention

Several factors combine to make COVID-19 outbreak prevention particularly challenging for border systems and for the pandemic response as a whole. Prevention of border failures needs a systematic approach, where risks are addressed or mitigated proactively. In particular, a full assessment of risk requires an understanding of the 'critical control points' where risk factors coincide to enhance and amplify one another. Figure 1 illustrates

Figure 1: Using a 'false negatives' approach to identify three key drivers of border failures.



false negatives as a driver of border failures and shows how they interact.

Using a 'false negatives' lens, the three drivers of border failures become more visible, indicating the three broad areas where preventive actions will make the most difference.

1. Pre-test probability is high at the borders:

- There is a *high risk of infections among persons entering New Zealand*, including returning New Zealanders and airline and shipping crew, particularly if they started their journey in a region with high levels of active transmission. Infections may be transmitted to others during travel (eg, on ships or aircraft), or in MIQ facilities after arrival in New Zealand, further increasing the pre-test probability of infection.

2. A high risk of false negatives is an intrinsic property of the COVID-19 pandemic:

- It can be *difficult to identify a case* before onward transmission has occurred. Cases can be asymptomatic or pre-symptomatic while infectious,[9] or they may present with atypical symptoms (eg, children presenting with diarrhoea). Without a basis for suspecting COVID-19 infection, individuals may not be tested. Even if tested routinely, as in the MIQ system, RT-PCR tests can return a false negative result if the timing of the test is not optimal.[10]
- COVID-19 transmission occurs not only via droplet spread during close contact, but also via airborne aerosol spread and, much less commonly, via spread from contaminated surfaces. Transmission can thus occur between individuals who are separated in space or time, making it *difficult to identify all contacts of a case*. Identifying contacts is important because contacts are the potential next cases in the transmission chain and the COVID-19 serial interval is short.[11]

3. The consequences of missing even one case through false reassurance are potentially severe:

- Border-associated workers are at a high risk of infection when they work in settings where there are infectious cases. They currently appear to experience a *high level of occupational risk* of COVID-19 infection, and this reason alone justifies stringent measures to keep them safe in their workplaces.
- However, border workers also present a *risk to their close contacts*

Table 1: Systematic approach to prevention of border failures.

	Examples of actions to:		
Populations	**1. Minimise the pre-test probability of infection**	**2. Minimise the risk of a missed case or contact**	**3. Minimise the consequences of a missed case or contact**
Incoming travellers	• Switch to a risk-based ('traffic light') system to identify travellers from jurisdictions with high and low levels of community transmission and adjust the intensity of border control measures accordingly.[3] • Pre-departure testing/quarantine for high-risk ('red zone') jurisdictions. • Review in-flight measures including mask wearing, ventilation and filtration of cabin air, physical distancing. (Despite reassurance from the airline industry,* there is convincing evidence of recent transmission on a long-haul flight to New Zealand despite in-flight precautions.)[12] • Develop a vaccine strategy for incoming travellers. • Systematically investigate all COVID-19 positive cases detected in MIQ to identify risk factors for infection that are potentially modifiable.	• Regular revision of COVID-19 diagnostic tests and testing regime to achieve optimal sensitivity of the process (eg, using frequent low-sensitivity point-of-care tests instead of less frequent high-sensitivity tests).[7,13] • Consider the use of detection dogs in airports and MIQ facilities.[14] • Involve users of the system in development of measures to increase ownership and adherence to physical distancing requirements.	• Active: Stringent infection control procedures in MIQ and port facilities to prevent incoming travellers from infecting other travellers or border-associated workers (see next row). Procedures need to include provision for emergencies (eg, media recently reported close contacts occurring during a fire alarm in an MIQ facility). • Passive: Built environment, particularly air filtration and natural or mechanical ventilation, designed to reduce airborne transmission,[15] and UV light as used in tuberculosis treatment settings may also have value for COVID-19.[15] • Development of purpose-built quarantine facilities outside main centres (eg, Ōhakea airforce base)[16]
Workers in border-associated occupations	• Supply PPE to hospital standards and institute environmental protections as above.	• Optimise timing of tests relative to transmission opportunities (ie, testing schedule linked to work schedule). • Review and optimise exemptions for some border-associated occupations. • In some settings (eg, Defence Force workers in accommodation facilities), test wastewater to 'capture' missed infections. • Use of contact tracing technology (eg, CovidCard) to track connections in time and space.[17]	• Physical distancing measures timed to their likely exposure history (eg, not to attend meetings or crowded indoor social events and to avoid settings such as aged-care facilities during set time periods). • Transmission measures timed to their likely exposure history (eg, wearing a mask in public spaces). • Workers and vulnerable whānau may need to reduce close contact during set time periods, following the model of increasing restrictions placed on Defence Force workers in this environment.[18] • Consider live-in arrangements for high-risk staff, as is being proposed in Victoria, Australia, and prohibit second jobs.[19]

Table 1: Systematic approach to prevention of border failures (continued).

Close contacts of workers in border-associated occupations	• Occupational safety protections as above to prevent infections in border workers.	• Monitor health status with a low threshold for testing (including testing children presenting with gastrointestinal symptoms and other less typical manifestations).	• Contacts of workers and vulnerable whānau may need to reduce close contact during set time periods. • Intensify contact tracing for border workers by identifying contacts prior to them commencing work.[19]
Whole population	• The whole population is protected when returning travellers and border workers are protected. • Targeted, equitable population vaccine strategy.	• Available and accessible COVID-19 testing. • Wastewater testing, particularly in areas close to border facilities. • Enhanced sentinel surveillance in selected communities.	• Additional protections at Alert Level 1 including mandatory masks in public transport, general practitioner waiting rooms, aged-care facilities, hospitals and so on, as previously recommended. • Built environment, particularly ventilation, designed to reduce airborne transmission.[15]

* https://www.iata.org/en/pressroom/pr/2020-09-08-012/

because these workers then mix with others (co-workers, household contacts and the general public) with few restrictions when away from border settings, as if their level of risk was the same as the general population. Some border-associated occupations involve workers travelling between regions in the course of their jobs, with potential for viral spread between regions.

- The default response setting of *Alert Level 1* includes minimal measures to prevent undetected transmission in public spaces; New Zealanders mix freely in crowded indoor settings and few wear masks unless required to do so.
- Virtually the whole country is *susceptible to COVID-19 infection*.

Given these inherent risks, it is unsurprising that Aotearoa is experiencing a high frequency of infection transmission from the border into the community despite the large amount of effort and resource deployed in the system.

Risk assessment: reviewing the border response in a systematic way

Agencies reviewing the border response using a risk assessment approach can prevent systematic underestimation of risk by aiming to understand and address the problem of false negative results. Such a review would consider measures to:

1. Minimise incoming infections to reduce the pre-test probability of infection.
2. Minimise the risk of a missed case or contact.
3. Minimise the consequences of a missed case or contact by increasing infection control measures in settings where infected and susceptible individuals mix in time or space. The stringency of measures needs to be adjusted proportionately to recognise the pre-test probability and risk of false negatives for each setting and population.

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Ideally, a multi-agency review would invite users of the system (eg, border workers and guests in MIQ facilities) to contribute their day-to-day experiences and insights about how systems work 'on the ground' and to identify points where there may be potential for undetected transmission.

Table 1 shows examples of actions that could be taken across these three areas.

Summary and recommendations

There is an urgent need for a review of the border system to prevent ongoing border failures that incur high wellbeing and economic costs. Multiple potential actions are listed in Table 1, and this table could be further populated during the course of the review as vulnerable points in the border system are identified.

Prioritisation would be needed and could be based on considerations such as effectiveness, acceptability and cost. High priorities are likely to include switching to a risk-based approach with additional measures, particularly pre-travel quarantine and testing, for travellers from high incidence countries, to prevent them arriving in New Zealand while infected. Quantitative assessment of false negative risks can be used to compare the likely effectiveness of proposed control measures.

Although COVID-19 is a new infection, it has been eliminated in Aotearoa New Zealand using well-established infection control measures such as border restrictions and quarantine. Similarly, sustained elimination will require the application of epidemiological principles in a systematic way to guide appropriate action, as shown in this editorial by the use of false negative results as a framework for management of risk at the borders. A high standard of strategic risk management is required because impacts on population wellbeing from breaches in control of this highly transmissible infection are substantial and should never be underestimated.

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Dr Telfar-Barnard reports other from New Zealand Ministry of Health, outside the submitted work.

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