What is Zero COVID (plus)?

Zero (No) COVID is an inclusive strategy that rests upon public health measures and population (a.k.a., herd) immunity to suppress community transmission.

Broadly speaking, there are two approaches to reducing viral spread. One can either remove **infectious** people from the population or remove people who are **susceptible** to infection. Isolating infectious people is the objective of public health measures that isolate or quarantine people who can transmit the virus. We will refer to this as a **containment strategy**. The alternative is to reduce the number of susceptible people through vaccination and natural immunity. We will call this the **immunisation strategy**. Both are problematic:

The **containment strategy** has an elusive endpoint – namely **suppression** – that is an inherently unstable (technically, it is an unstable fixed point or endemic equilibrium). This is because introducing infected people into a susceptible population will cause the virus to spread again. In the absence of eradication (i.e., elimination everywhere), a pure containment strategy would require certain populations to be eternally sequestered via quarantine and border controls. Failures of quarantine would require ongoing mitigations that underwrite containment, such as lockdowns and travel restrictions.

Conversely, the **immunisation strategy** has a stable fixed or endpoint, in which there is a constant rate of infection and associated morbidity. The level of this morbidity (e.g., long COVID) and accompanying mortality (i.e., death rates) depends upon the (potentially high) prevalence of infection at endemic equilibrium. Both containment and immunisation strategies could be considered untenable. Is there another way?

Zero COVID is a third way that uses containment (i.e., public health measures) to minimise the prevalence of infection afforded by population immunity. The endpoints of a successful strategy are containment, suppression and elimination. Elimination would correspond to a limiting case when the prevalence was zero that – in the absence of eradication – may be sustainable for periods of time; e.g., the elimination of measles.

What does zero COVID entail?

It requires a strategic acknowledgement that public health measures are a fundamental part of the strategy necessary to minimise the prevalence of infection during the acquisition of population immunity. Practically, this means ‘surge testing’ and ‘supported (or managed) isolation’ wherever the prevalence is not shrinking. In other words, it requires a bilateral and sustained response, where equal emphasis is placed on vaccination and public health containment measures.

What are the likely long-term outcomes under zero COVID?

In the absence of global elimination (i.e., eradication), it is likely that low levels of prevalence will persist indefinitely. Over the next few years, with a contained spread of the virus and its variants – plus a global vaccination programme – all susceptible and exposed people should eventually acquire a degree of immunity, **with the exception of young children who have not been exposed to the virus**. This means viral transmission may become increasingly limited to young children – and the age demographics of transmission will shift towards the profile associated with seasonal influenza.

Clearly, this is speculative but is the endemic equilibrium people have in mind when talking about repeated vaccinations – and the vaccination of children. Given that the pathogenicity of SARS-CoV-2 in younger age groups is negligible, this endemic equilibrium may be a suitable aspiration. In the interim, minimising prevalence in the general population is imperative. In other words, ensuring that population immunity is mediated by vaccination and not pathogenic infections.

What are the principles behind zero COVID?

The underlying principle behind zero COVID could be summarised as "leave no man behind". In other words, the question is not "what is the best intervention?" It is "which intervention is failing?". For example, a failure to implement proper public health measures could result in a **high prevalence endemic equilibrium** under an immunisation strategy. Similarly, a myopic focus on containment will lead to a **never-ending cycle of lockdowns and quarantine**. This principle applies at all scales. For example, isolating infected people within their community, and isolating infected communities with travel restrictions. So, what kinds of containment measures do we have at hand for minimising prevalence?

The many faces of containment

Formally, **containment precludes exponential growth**. Exponential growth (as scored by the R-number) is the product of three factors. Namely, **contact rates**, **transmission risk** and the mean **period of infectiousness**. This nicely partitions the different interventions that can be deployed: contact rates are reduced by lockdowns, travel restrictions and quarantine. Transmission risk is reduced by socio-behavioural responses, such as mask wearing and social distancing. Finally, the infectious period is the target of public health measures that aim to find and isolate infectious people. The ensuing three levels of interventions work hand in hand – and are therefore all necessary components of a containment strategy. But, how would this be deployed under zero COVID?

Strategic implications

Containment requires an escalation of public health measures in any community with the potential for exponential growth in viral transmission. One can leverage this in a clear and quantitative fashion by noting that – for any community with a given prevalence of infection – there is a critical incidence that corresponds to a (transient) endemic equilibrium, where R is exactly one. This means that enhancing containment measures in communities that exceed this threshold will reduce the R-number and preclude exponential growth. Prevalence will then fall, underwriting the imperative to minimise prevalence. This strategic approach has four implications:

- Containment and public health measures should be deployed in response to the incidence of infection in a context-sensitive way, where the context depends upon the local level of prevalence: e.g., at the level of (lower tier) local authorities.

- These responses are time-sensitive and are specified by the incidence and prevalence of infection. In short, there is a clear and quantitative way of implementing zero COVID in terms of **threshold crossings**.

- Although thresholds can be defined precisely it may not be possible to predict when these thresholds will be reached or breached. This precludes a roadmap with predefined dates.

- Finally, zero COVID requires precise and accurate real-time estimates of incidence and prevalence.

Mechanics of containment

Under a simple SIR model of viral spread, changes in prevalence can be expressed as the incidence of new cases minus the rate at which people recover:

$$\frac{dp}{dt} = r - \frac{p}{\tau}$$

$$K = \frac{\ln R}{\tau} = \frac{d \ln p}{dt} = \frac{1}{p}\frac{dp}{dt} = \frac{r}{p} - \frac{1}{\tau}$$

$$r = (1-p) \cdot c\kappa \cdot p$$

$$R = c\kappa\tau$$

$$\tau \frac{d \ln p}{dt} = (1-p) \cdot R - 1$$

$$(1-p_0) \cdot R = 1 \Rightarrow p_0 = 1 - \tfrac{1}{R}$$

This means exponential growth is determined by the incidence, prevalence and period of infection. To preclude exponential growth, the incidence has to be less than the prevalence divided by the mean infectious period.

$$r \leq \frac{p}{\tau} \Rightarrow K < 0 \Rightarrow R < 1$$

For example, if a local authority had a prevalence of .5% (i.e., 500 people per hundred thousand), a serial interval of 5.29 days gives a critical incidence of 94.5 people per hundred thousand per day. An incidence greater than this—or a lower threshold—calls for an escalation of public health measures.

- **Exponential growth** (*K*): that can be expressed as the rate of change of the logarithm of prevalence, which is the incidence divided by prevalence
- **Prevalence** (*p*): the proportion of people who are infected
- **Incidence** (*r*): the rate at which people become infected, which depends upon the effective contact rate and transmission risk
- **Mean infectious period** (τ): under simplifying assumptions this is related to the **serial interval**. The infectious period can be reduced by testing, tracing and *isolation*
- **Contact rate** (*c*): probability of a close contact
- **Transmission risk** (κ): probability of infection given close contact
- **Reproduction ratio**: R number

Do we have appropriate epidemiological measures for zero COVID?

To implement the containment part of zero COVID, real-time estimates of incidence and prevalence are required at an appropriate level of granularity. These estimates are available but have not, so far, been used to inform local or national responses. Rather, national responses appear to be predicated on retrospective estimates based on proxies such as the incidence of new confirmed cases or hospital admissions. This is problematic for two reasons.

- Estimates of the R-number based upon (Bayesian regression) curve fitting of past data are, necessarily, out of date (usually by 16 days). This lag precludes their use in guiding real-time interventions (e.g., 'surge testing'). **Real-time estimates** furnished by data assimilation and deconvolution procedures are therefore necessary.

- Basing criteria on the incidence of confirmed cases (e.g., a certain number per hundred thousand per week) is not useful. This is because the incidence of confirmed cases fluctuates with testing rates, the relative sensitivity of different tests (e.g., PCR versus LFD), and selection biases (e.g., who is tested). Finally, fixed incidence thresholds do not accommodate local prevalence. This calls for **estimation of the latent incidence and prevalence** under an appropriate convolution or generative model.

Summary

Zero COVID is a principled and inclusive strategy that combines monotheistic approaches; namely, containment and immunisation. Zero COVID rests upon basic epidemiological principles and established public health measures that are the cornerstone of infectious disease control. The objective is to realise a minimum prevalence endemic equilibrium based upon real-time quantitative estimates of local prevalence and infection. The 'zero' in zero COVID is not about eradication. It connotes a zero tolerance of viral spread. It mandates that no door should be left open to COVID-19.