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Public health, health systems and palliation planning for COVID-19 on an exponential timeline

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Exponential epidemic growth has been clearly demonstrated for COVID-19 in every country it has touched, with ascertained cases growing from 25 at the start of March in Australia to over 4000 cases four weeks later. For every ascertained case, there may be anywhere up to 9 infections that are not detected. (1) This silent component of spread is likely driven by asymptomatic (2) or mild infection, especially in younger people. In countries which restrict testing to symptomatic high-risk people only, there will be silent growth of undetected infection until the epidemic is large enough to be felt in the health system. (3)

The epidemic in China was largely localised through January, with small numbers of imported cases in other countries. Following a lockdown on January 23rd, it peaked on February 5th, (4) and has declined since – but as the cases decreased in China, COVID-19 began surging in other countries by late February. Asian countries such as South Korea took an aggressive approach to testing and achieved control. (5) In contrast, a more relaxed approach saw Europe becoming the new epicentre, followed by the United States of America, (6) which had epidemic growth because of major testing failures. In Italy, Spain and parts of the United States, health systems capacity has been exceeded, with resulting shortages of intensive care beds and ventilators.

Case fatality rates (CFR) have varied globally, from 0.85% in South Korea to over 10% in Italy. (7) Whether CFR is 0.85% or 10%, this is orders of magnitude higher than seasonal influenza (8) or even the 2009 pandemic. (9) Two factors influence CFR – testing and capacity to ventilate. More widespread testing will result in identification of mild and asymptomatic cases, as in South Korea, and will result in a lower apparent CFR. Given respiratory failure is the leading cause of death from COVID-19, the inability to ventilate patients will drive CFR up. In Germany, the rate of ICU beds per head of population is 29/100,000 compared to 12 per 100,000 in Italy, (10) so despite having over 52,000 cases, capacity was not exceeded. In Italy and Spain, however, ICU capacity was exhausted. In contrast in China, large hospitals were built in a matter of days to ensure capacity to

ventilate patients was not lost, keeping CFR lower than Italy. From that perspective it is key that Australia flattens the curve to keep health system capacity available to ventilate every patient that needs it. We have 9.1 ICU beds per 100,000, less than Italy, although Australian capacity has been expanded as part of COVID-19 preparedness. (10)
Central to flattening the epidemic curve is R0, the basic reproductive number. R0 is the number of secondary cases arising from one index case in a completely susceptible population. The epidemic threshold is defined mathematically as when the R0 exceeds one, which creates conditions for an epidemic, although an epidemic may not always occur. If the R0 is less than one, an epidemic cannot be sustained because one infectious case infects less than one other person on average, and infection will die out. The best estimates of R0 for COVID-19 lie between 2-3. (11) Public health disease control strategies such as vaccination, social distancing or travel bans aim to reduce the R value down below one, thereby stop the epidemic. The R modified by such measures is manifested as "flattening of the curve", which is dampening the natural trajectory of the epidemic which would otherwise occur.

Closely related to R0 is the concept of herd immunity. Herd immunity is a concept related largely to vaccination programs. It is the observation that when enough people are immune to an infection, even people who are non-immune are protected because the number of non-immune individuals is too small for infection to spread. Immunity can be gained by infection, or by vaccination. Unless we can eradicate an infection, vaccination is the only way to control it long-term. However, a range of non-pharmaceutical measures will also control epidemics, and can be used in the short to medium term to reduce the size of the epidemic, manage demand in the health system and save as many lives as possible.

The required proportion of people in a population that need to be immune to induce herd immunity (H) is related to the R0 and calculated by the formula $H=1-(1/R^0)$.(12) If we assume R0 is 2.6, we need 61% of the Australian population to be immune to gain herd immunity for the remaining 39% of people. Therefore, any desire to "allow" some transmission (an idea floated by some experts in the UK and Australia) will only cause more disease and death without any benefit at infection rates <60%. (13) If >60% of Australians were infected, we will have a worst-case scenario, will endanger our health workers, and rapidly exhaust our health system capacity. Further, allowing transmission of COVID-19 will not get rid of it – it causes recurrent, cycling epidemics of a mass scale, as seen with measles, mumps, rubella, smallpox and all other epidemic infectious disease prior to vaccination. We would also see high morbidity and mortality in older people as a result as 50% of the population is aged over 40 years. Younger people too, would be affected. In the US, 36% admitted to ICU were aged 45-64 years and 12% were aged 20-44 years. Deaths in the US have been seen in all age groups above 18 years. (6). Large studies also show that children can have severe disease or die – 50% had mild disease, 30% moderate and 6% critical illness. (14) In one study a child aged 10 months died. (15) Young people and children tend to transmit respiratory infections, most intensely in society, because they have the highest contact rates. (16) This means that mild or asymptomatic infection in young people could be a driver of epidemic growth. Many people live in multigenerational arrangements, so young people becoming infected could result in older people or people with chronic diseases becoming ill.

The deputy Chief Medical Officer suggests, presumably based on modelling which is not yet available publicly, that 15 million Australians may get infected and there may be 150,000 deaths.(17)

We are a high-income country of 26 million people, and it should be noted in China with nearly 1.4 billion people, even if true case numbers were 100 times greater than reported, less than 1% of their population were infected, and 3298 people died. (7) We may not be able to achieve China-style lockdowns, but surely, we can control the disease enough to spare our health system and minimise morbidity and mortality. Modelling for Australia suggests we may run out of ICU beds in April if we do not alter the epidemic trajectory. (18).

The protection of the health workforce is also key to our response. The other impact of health system overload is the infection of health workers, already vulnerable because of the failure to stockpile adequate personal protective equipment (PPE), thus further compromising the ability to respond. Studies have shown that viable SARS-CoV-2 can be found widely on surfaces and in the air three hours after aerosolization, highlighting the risk of airborne transmission. (19) This is supported by the finding of virus in air outlet fans in the hospital room of an infected patient. (20) It is likely therefore that transmission is multimodal, including respiratory and contact. In the US, critical shortages of personal protective equipment forced health workers to use plastic garbage bags as gowns, with some dying. The US Centers for Disease Control initially recommended respirators for health workers treating COVID-19, but as shortages worsened, downgraded to surgical masks and even bandanas. (21) We must flatten the curve to ensure that Australian health workers are not placed at risk by PPE shortages. Further, if beds are full with COVID-19 patients and a large proportion of health workers are infected, the ability to treat other serious conditions like cardiovascular disease will be reduced.

Another consequence of health system overload will be the need for community palliative care for COVID-19 patients unable to access hospital care. While the potential for mass mortality is sometimes considered in major disaster plans, the issue of mass palliation is often neglected. In severe COVID-19 pneumonia where respiratory support is not available there is a progressive decline of the patient until ultimate demise associated with severe hypoxaemia, cardiac failure, acute respiratory failure, and sepsis. In the days and hours prior to death, however, the patient will usually suffer from progressive dyspnoea, chest pain, delirium and become progressively moribund and immobile prior to death. (22) Provision of equitable, compassionate, safe and dignified end of life care to COVID-19 cases unable to be offered lifesaving critical care is fundamental to ensuring the integrity of the Australian social fabric, and moral and mental welfare of potentially large swathes of the population. Up to 40% of the elderly in some age brackets live alone, complicating how to achieve what is necessary and right. Planning around the country for this worst-case outcome is currently underway, but requires significant resources, personnel and government support and a national approach.

The impact of interventions is generally seen 1-2 incubation periods from the implementation. The flattening of the curve seen in Australia from March 24th probably reflects the impacts of rolling travel bans implemented from March 5-10th. However, NSW is the epicentre of infection in Australia, and the recent lapses in border control with the Ruby Princess and other cruise ships may see an increase in cases again by mid -April. In light of this, a comprehensive lock-down including school closure buys time to scale up testing. A slow trickle of phased interventions and a "wait and see" strategy will leave us dealing with COVID-19 in the health system for longer. For doctors, it is no consolation to hear that "we are not like Italy, Spain or US." All are high income countries that used a restricted testing strategy, unlike our Asian neighbours. The United Kingdom is probably the

country whose trajectory we are most similar to. They are facing a strain on the NHS and shortages of PPE, despite confident assertions by authorities only weeks ago. The UK, like Australia, used restricted testing and did not test asymptomatic close contacts and other high-risk groups (23).

To ensure Australia continues to flattens the curve, social distancing is especially important because of asymptomatic transmitters of infection. Being unable to identify infectious cases makes disease control much harder. Until we have a vaccine, all we have available in the toolkit is social distancing and travel restrictions, along with isolation of sick people and quarantine of contacts and return travellers. The WHO recommends school closure during a serious pandemic, and outlines the evidence that comprehensive, simultaneous social distancing measures and early school closure work better than phased or gradual measures.(24) China has demonstrated the feasibility of a short lockdown followed by phased lifting of restrictions. The Chinese epidemic curve (4) shows the success of lockdown, implemented in Wuhan on January 3rd, while the epidemic was in the exponential growth phase with thousands of new cases a day. Within 1 incubation period, cases started to fall. China began lifting restrictions on February 9th, just over 1 incubation period from the lockdown. They have continued to gradually lift restrictions, from a more manageable baseline position of far fewer cases to track and contain, all within 8 weeks.

A lockdown is a temporary measure which can result in substantial reduction of epidemic size, more manageable case numbers and a flattening of the curve so that health system capacity is not exceeded and economic recovery can occur sooner. Lockdown can be relaxed safely in a phased manner, but must be accompanied by extensive testing, including of asymptomatic high-risk people such as close contacts, evacuees and people in institutional outbreak settings. To ensure all community cases are detected, any doctor should be able to exercise their clinical judgement and order a test for COVID-19. Failure to test asymptomatic at-risk people and allow wider community testing will result in undetected transmission in the community and a bounce-back of the epidemic as lock-down restrictions are lifted. The only two countries to achieve sustained flattening of the curve to date are South Korea and China. South Korea has achieved this with more targeted, short lockdowns along with extensive testing. (5)

The risk of a phased and gradual approach is continued epidemic growth, potential failure of the health system, and a far longer road to recovery. We have examples of countries which have failed and succeeded, which can guide such a response. Epidemic control is time critical, because epidemics rise exponentially. There is no real choice available between jobs and lives – failing to save lives now will result in more net job losses and a longer recession. In addition to expanded testing, key strategies to accompany a lockdown must be a financial aid package that is accessible and leaves no person in need; a mental health and domestic violence package with outreach capability; a communications and social engagement package; a physical fitness package and other required support.

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