The COVID-19 pandemic is unprecedented and may have long lasting global impacts. In addition to direct health and economic losses, it has had multiple flow on effects to supply chains, travel and trade globally. The infection can spread silently and remain undetected until the health systems impacts become so severe that hospital bed capacity and staffing capacity is exceeded. The economy and public health disease control are not competing choices – without epidemic control, the economic losses will be far higher.

Epidemic control can be achieved long term with a vaccine, but until one is available, we have only non-pharmaceutical measures at our disposal. The four pillars of this are (1) identifying every case rapidly with extensive testing, and isolating cases. (2) Tracking and quarantine of contacts (3) Travel restrictions (4) Social distancing (including lockdown) to reduce contact and transmission between people. Countries which are strong in 1-3 above may achieve epidemic control with targeted use of social distancing (as seen in South Korea), but weakness in any of 1-3 necessitates a strong approach to (4). Australia has a weakness in (1) because of test kit shortages through most of February and March, and restricted testing policy, which means a proportion of cases remain undiagnosed. However, Australia has taken a slow trickle approach of phased, targeted restrictions to reduce social contact along with continued restricted testing. Epidemic growth is exponential, leaving little time for decision making. On March 1st we had 25 cases and now, nearly at the end of March we have over to 4000 cases. Whilst some of these are travel imported cases, there is likely a silent epidemic which has not yet been detected with widespread community transmission of infections which we have been unable to detect because of restrictive testing and shortage of test kits.

On a range of indications, we are deeply concerned about the prospect of Australia losing control of the epidemic to a degree which would exceed health system capacity and result in far greater numbers of cases, more health and economic losses, and a longer time to societal recovery. While a flattening of the curve has been seen since March 24th, this is likely the impact of the travel bans implemented between March 5-10th. It is too early yet to see an impact of social distancing, and lapses like the Ruby Princess cruise ship, together with lack of testing for asymptomatic high-risk people, may allow transmission to continue in the community. Modelling shows that the greatest impact on the epidemic will be with the most severe of social distancing measures (such as lockdown), combined with enhanced testing and quarantine. The argument that such measures need to be long-term (6-12 months) is incorrect. China has demonstrated the feasibility of a short lockdown followed by phased lifting of restrictions. A short, sharp lockdown of 4-8 weeks will improve control of the epidemic in Australia, reduce case numbers more rapidly and bring us to a more manageable baseline from which phased lifting of restrictions and economic recovery can occur. If we fail to do this, we face continued epidemic growth, potential failure of the health system, and a far longer road to recovery. A comprehensive lock-down also buys time to scale up required testing, capacity for rapid case identification and isolation, and for thorough tracking and quarantine of contacts (interventions 1 & 2 listed above) aided by novel smart phone apps and related technologies, as deployed with great success in South Korea. For lockdown to successful in a short, sharp burst, it must be accompanied by scaled up testing capability and broadened testing criteria to ensure that every new case can be identified rapidly during the lockdown and in the follow up phase, when restrictions are lifted. The two key elements of expanded testing are testing of asymptomatic, high risk people (contacts, evacuees and people in enclosed outbreaks such as...
cruise ships, aged care facilities, prisons) and allowing doctors to use their clinical judgement to order a test. These are needed to identify community transmission. Expanded testing will need a more flexible approach to solutions, including enabling domestic capacity to scale up, procurement from overseas or actively asking for help from another country who has achieved testing at scale. Without such an improvement in the public health response capacity, there will almost certainly be a bounce-back of the epidemic as lock-down restrictions are lifted. We have examples of countries which have failed and succeeded, which can guide such a response.
Overview

The world is in the midst of an unprecedented pandemic of COVID 19, which originated in China. Europe is currently the epicenter, but an exponential increase in cases is being seen in the US, Australia and other countries. COVID-19 is caused by a virus, SARS COV 2, which infects the respiratory tract and causes a spectrum of disease from a mild illness to severe and fatal pneumonia. The major difference from SARS is that spread can occur from people without symptoms. This means we cannot identify all infected people, and they can go on to cause undetected infections in the community, much of it driven by mild or asymptomatic cases. We may not realise the degree of spread until it grows so large that our hospital system is severely affected – which is the case in other countries such as the US, UK, Spain and Italy, where many generations of silent transmission have occurred and failed to be detected because of lack of testing. It is spread by the respiratory route and by contact, and it takes about 5 days on average, and up to 14 days usually, for someone who is exposed to become ill (incubation period). This means it will take 14 days to see the impact of interventions. Whilst the death rate is lower than SARS, it is orders of magnitude higher than influenza and it is highly infectious - on average one person infects two to three other people. This makes it an epidemic infection with exponential growth capacity – epidemics grow in size rapidly, over days or weeks, leaving very little time for policy decision making. A delay of a week can result in a much larger epidemic, as shown below. This means public health interventions should be used early for maximal success. The longer the delays, the larger the epidemic, the greater the untraced infections and the longer the time to achieve disease control.

The graph also shows the epidemic curve in Australia and key events, noting that authorities are not worried currently because about half of all cases are imported by travel. This proportion has reduced over time, reflecting increasing transmission within Australia. Some of this is known and explainable transmission (for example close contacts of return travelers with COVID 19), but some cases have no known contact with COVID 19 cases and have not travelled. The source of infection entering Australia was travelers, as well as evacuation of people from Wuhan on February 3, and from the Diamond Princess Cruise ship on February 20. The first community case without any known risk factors occurred in early March, linked to a nursing home outbreak, four weeks after the first Wuhan evacuation. This suggests there may have been undetected asymptomatic infections which resulted in undetected transmissions. The same relationship of a surge in community cases to evacuations is seen in the US, including the first unexplained community case being located in the same town as an airforce base which received evacuees a month earlier. Australia may have undetected chains of transmission in the community arising from the evacuations on February 3rd and February 20th. In both cases a surge occurs after 2 incubation periods. The travel bans on South Korea and Iran occurred on March 5th, and on Italy on March 10th. We would therefore expect to see an impact of these bans in flattening the curve up to April 2-7th. What happens to the curve after that will indicate the extent of community transmission. Any rise occurring before April 7th will also be concerning, as it will indicated transmission events greater than the reduction in transmission caused by the travel bans.
Asymptomatic infection

Diseases with asymptomatic infection are much harder to control than those where spread only occurs from people with symptoms. There has been a degree of denial of the importance of asymptomatic infection, but numerous studies have confirmed it. \cite{Chan_2020, Lin_2020, Nishiura_2020}. Europe, including Italy, Spain, France and Germany, is experiencing the most severe epidemic, followed by the United States. The serious situation in Europe and the US has been driven by a lack of testing capacity, restricted testing policy, denial of evidence and a failure to detect transmission within the community. On February 14th, the Spanish health minister reassured the country there was no COVID-19 in Spain. Just 6 weeks later, the country has over 70,000 cases. Italy is close to exceeding the number of cases in China, and the United States has over 100,000 cases. Just 3 weeks ago the United States had only 250 cases. The common element to these countries, and Australia, is restricted testing. Only people with symptoms who have travelled or been in contact with a known cases are tested. On the Diamond Princess, the Japanese tested almost everyone and of 634 infections, a total of 328 were asymptomatic. \cite{Mizumoto_2020}. This indicates a substantial role of asymptomatic transmission and the critical importance of testing widely to identify all cases and stop transmission.

Disease control measures

Vaccines are the most effective way to control epidemic diseases. In the absence of a vaccine, there are four pillars to containing an epidemic:

- Detecting and isolating all cases – the WHO says we must “test, test, test”, and this has been the secret to South Korea’s visible flattening of the curve.
- Tracing all contacts of cases, quarantining them and monitoring them for symptoms. If they develop symptoms, they need to be isolated and tested. In general there are 9-10 close contacts per case. Human resources for such work could be scaled up within a month, and can be made more efficient by novel use of smartphone apps and integrated outbreak management systems, as used with success in South Korea.
- Travel bans to reduce the risk of imported infections. Australia has done this with great success and extended bans as the situation has changed globally.
- Social distancing – any measure which reduces the contact between people will work. These include banning of mass gatherings, working from home orders, closure of schools and other
restrictions. A lockdown is a complete cessation of social contact, as was used in Hubei province, China. These can be done proactively when the epidemic is small, or reactively when the epidemic is large. It is most effective as a proactive measure.

The first graph below shows the flattening of the curve in South Korea compared to failure to do so in Europe and Iran, which all began surging at the same time. The approach of European countries has been similar to Australia’s approach. Singapore, which is cited as a justification for a slow trickle, soft approach has not contained the epidemic, with cases surging and further lockdowns implemented last week.

Flattening of the epidemic curve in South Korea compared to Iran, Italy, France and Germany. Graph provided by Prof Raina MacIntyre, UNSW

The next graph shows the success of lockdown in China, implemented in Wuhan on January 3rd, while the epidemic was in the exponential growth phase. Within 1 incubation period (2 weeks), cases start 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 fewer cases to track and contain.
A lockdown is a temporary measure which can result in reduction of epidemic size, more manageable case numbers and a flattening of the curve (see below) so that health system capacity is not exceeded. China has shown that a lockdown can be highly effective and can be relaxed safely in a phased manner when daily case numbers are much lower.

The only two countries to achieve flattening of the curve to date are South Korea and China. The current pandemic meets the WHO guidelines for extensive measures including school closure {Organization, 2019 #338}. We have seen failures arise from the staggered, slow trickle and localized measures taken in Italy, the UK and US.
In Australia, we have two critical weaknesses in the response – inability to test at scale through most of February and March, (which will result in missed cases), and shortages of PPE for health care workers, even allowing for some stock arriving in late April. This does not afford us the luxury of a slow trickle approach. It is essential we use all available measures to compensate for these weaknesses, to ensure our health workforce is able to provide the best response and is not placed at risk. Exceeding health system and PPE capacity may result in collapse of the health system when health workers are forced to work without adequate PPE, are unable to work due to illness, or have died. The surge capacity required for an uncontrolled epidemic may result in over 80% of beds being occupied by COVID19 patients and inability to treat other acute illnesses such as heart attacks and strokes.

**How is Australia tracking?**
We can look at case numbers alone, which were growing exponentially until March 24th. On March 1st we had 25 cases and at the end of March we have almost 4000 cases. We can also look at doubling time, the time taken for case numbers to double. The longer this is, the better. The graph below shows the comparative trends in doubling time in several countries. Australia and the United states show the most concerning trends of shortening doubling time. This usually corresponds to the exponential growth phase of the epidemic. While this graph shows reduction in the doubling time until last week, and update would show an increase in doubling time by March 30th, reflecting the success of the travel bans.

![Graph showing doubling time in seven countries](image)

**Trends in doubling time in seven countries.** Graph provided by Professor Richard Nunes-Vaz, Flinders University

Another way of looking at this is through its impact on the reproductive number, R, which is the number of secondary cases caused by one infectious case. Effective disease control brings R below 1, and poor disease control results in R remaining at a value above 1.
7-day sliding window of effective reproduction number up to 22 March 2020

Epidemic is decaying if effective R is under red line

Australia  Germany

Italy  Japan

Singapore  South Korea

Spain  Sweden

UK  US

End date of 7-day sliding window

CC-BY-NC-SA Tim Churches (UNSW Medicine) & Nick Tierney (Monash)
Data source: Johns Hopkins University
Australia is not showing any impact on epidemic control, until March 24th. We are now seeing an impact of the travel bans between March 5-10th. Given the cruise ship lapses in mid-March, it remains to be seen if these gains will persist.

**The false argument of economy vs disease control**
While the economic toll of COVID-19 hits worldwide and people face joblessness, a common narrative poses public health disease control and the economy as valid but competing choices. We cannot wish away this pandemic and remain in denial. Without concerted disease control efforts, the epidemic will be larger, economic toll will be far greater and recovery will take much longer. Public health disease control is essential for economic recovery from a pandemic and is not a mutually exclusive prospect.

**The strategy of lockdown for Australia**
On all indications (the epidemic growth, falling doubling time and failure to reduce the reproductive number), Australia has not contained the epidemic as well as it could have. The travel bans have been the most successful and strongest element of our approach. A phased approach of gradually increasing interventions whilst keeping schools open will have some effect, but likely not enough. It
will leave us dealing with COVID 19 for much longer. A short, sharp lockdown for 2-3 incubation periods (4-6 weeks), combined with scaled up testing capacity and widespread testing, as undertaken by South Korea, would impact the epidemic substantially. Dr Tim Churches and Professor Louisa Jorm have conducted modelling of the impact of lockdown and other interventions in Australia. They modelled six scenarios in a hypothetical population of 100,000:

- **Scenario 1**: Ramp up self-isolation from days 1 to 15, such that the proportion of newly symptomatic and/or diagnosed individuals who self-isolate on each successive day of illness increases from 3% to 33%.
- **Scenario 2**: As for Scenario 1 except that the proportion of individuals who self-isolate increases from 3% to 66%.
- **Scenario 3**: Scenario 1 plus ramp up of moderate social distancing from day 15, such that the daily number of interactions in the population overall is reduced from 10 to 5 over a further 15 days, where it stays for a further 45 days, before increasing back up to 10 (i.e. total of ramp-up plus maintenance period is 60 days).
- **Scenario 4**: Scenario 1 plus 30-day lockdown from day 30, such that the daily number of interactions in the population overall is immediately reduced from 10 to 2.5, then increases back up to 10 from day 60.
- **Scenario 5**: As for Scenario 4 except lockdown is for 60 days, lasting until day 90.
- **Scenario 6**: Scenario 5, with the addition of self-isolation with high compliance commencing at 90 days (66% of newly symptomatic and/or diagnosed individuals self-isolate on each successive day of illness).

The results are shown below below.
Under all scenarios, the COVID-19 epidemic curve is substantially flattened AND shrunk, with far fewer cases and deaths overall. Under most scenarios, the number of cases requiring hospitalisation briefly overwhelms assumed hospital capacity, but at different time points. Scenario 1 demonstrates that moderate compliance with self-isolation substantially dampens the epidemic and reduces deaths by around one-third. Scenario 2, which perhaps resembles the extreme case finding and enforcement of self-isolation and quarantine enacted in South Korea, results in almost complete suppression of the epidemic, with no second peak in cases, or “rebound”. Scenario 3, which combines ramp up of self-isolation and social distancing and is perhaps analogous to the Australian response to date, results in reduction in cases and deaths by around one-third. A rebound in cases that is much larger than the initial, suppressed, peak occurs at around day 90.
Among the “lockdown” scenarios, Scenarios 4 and 5 demonstrate a similar rebound in cases, which is delayed according to the duration of the lockdown. A small and very delayed rebound occurs in Scenario 6, which combines lockdown and subsequent high compliance with self-isolation. These Australian findings are broadly consistent with those produced by modellers at Imperial College using scenarios for the United Kingdom and USA. The rebounds in the lockdown scenarios are at a much lower level than the less restrictive scenarios, and would allow health, social and economic recovery from a lower baseline of cases.

Testing scale up

For lockdown to successful in a short, sharp burst, it must be accompanied by scaled up testing capability and broadened testing criteria to ensure that every new case can be identified rapidly during the lockdown and in the follow up phase, when restrictions are lifted. We recommend:

1. Expanded capacity for currently used RT-PCR testing (testing for fragments of viral DNA from sputum, nasal and throat swabs.
2. Concerted campaign of education for pathology collectors and clinicians collecting samples that a throat swab is insensitive – a sputum is the most sensitive sample, followed by a nasopharyngeal swab and lastly a throat swab.
3. Repeat testing (at least 3 tests) must be done on suspected cases when initial RT-PCR test is negative, based on evidence of false negatives.
4. If procurement of swab kits and reagent are unsuccessful, suggest exploring options with South Korea for options to scale up testing.
5. Broadened inclusion criteria for testing – any request for testing of a febrile patient.
6. Drive-through testing sites for any community member who wishes to be tested.
7. Invest in expanding the capacity of Australian laboratories to conduct serology for COVID-19 at scale, including technologies such as Luminex for high volume ELISA testing.
8. Develop or source a commercial serological test for widespread testing. A single high titre or rising tires from acute and convalescent sera could indicate active infection and will be more sensitive than RT-PCR and could be done if swabs are negative.
9. Serology for screening for COVID-19 exposure and rapid age-specific Australian epidemiology. Residual sera from private pathology labs has been successfully used for national serosurveys in the past and can be used for COVID-19.
10. Enhance national syndromic surveillance for pneumonia using existing networks such as ASPREN.
11. Invest in rapid point of care tests which have been developed on the Cepheid platform. Numerous Cepheid machines are available in Australia already. These can be used for testing in high intensity outbreak settings such as aged care facilities or cruise ships.

Suggested new testing criteria to accompany lockdown strategy

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<tr>
<th>Criterion</th>
<th>Current</th>
<th>Proposed</th>
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<tbody>
<tr>
<td>Returned from overseas in the past 14 days or cruise ship and (during travel bans)</td>
<td>No (only if develops symptoms)</td>
<td>Yes, while the global epidemiology remains serious. Can be reviewed and changed to symptomatic only if global incidence reduces.</td>
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<tr>
<td>Close contact with a confirmed COVID-19 case in the past 14 days</td>
<td>No (only if develops symptoms)</td>
<td>Yes</td>
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<tr>
<td>severe community-acquired</td>
<td>Yes</td>
<td>Yes</td>
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pneumonia or hospitalised febrile respiratory illness with no clear cause

| Healthcare worker or aged care worker who works directly with patients and requests testing | No (only if develops fever) | Yes |
| Evacuated from a high risk setting such as a cruise ship or high incidence country (test all, regardless of symptoms) | No (only symptomatic) | Yes |
| Working or living in an aged care facility or other closed residential facility; Military operational settings; Boarding schools; Correctional facilities; Detention centres; Aboriginal rural and remote communities, in consultation with the local PHU; Settings where COVID-19 outbreaks have occurred, in consultation with the local PHU (test all, regardless of symptoms) | No (only symptomatic) | Yes |
| For cases not meeting criteria above, test if a medical practitioner in their clinical judgement feels testing is warranted (this would include Individual patients with illness clinically consistent with COVID-19 in a geographically localized area with elevated risk of community transmission, as defined by PHUs, but be broader to allow early detection of community cases.) | No | Yes |

References

