An imperfect tool: COVID-19 'test & trace' success relies on minimising the impact of false negatives and continuation of physical distancing.

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Abstract

Background: Following a consistent decline in COVID-19-related deaths in the UK throughout May 2020, it is recognised that contact tracing will be vital to relaxing physical distancing measures. The increasingly evident role of asymptomatic and pre-symptomatic transmission means testing is central to control, but test sensitivity estimates are as low as 65%.

Methods: We extend an existing UK-focused branching process model for contact tracing, adding diagnostic testing and refining parameter estimates to demonstrate the impact of poor test sensitivity and suggest mitigation methods. We also investigate the role of super-spreading events, providing estimates of the relationship between infections, cases detected and hospital-

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isations, and consider how tracing coverage and speed affects outbreak risk.
Findings: Incorporating poor sensitivity testing into tracing protocols could reduce efficacy, due to false negative results impacting isolation duration. However, a 7-day isolation period for all negative-testing individuals could mitigate this effect. Similarly, reducing delays to testing following exposure has a negligible impact on the risk of future outbreaks, but could undermine control if negative-testing individuals immediately cease isolating. Even 100% tracing of contacts will miss cases, which could prompt large localised outbreaks if physical distancing measures are relaxed prematurely.
Interpretation: It is imperative that test results are interpreted with caution due to high false-negative rates and that contact tracing is used in combination with physical distancing measures. If the risks associated with imperfect test sensitivity are mitigated, we find that contact tracing can facilitate control when the reproduction number with physical distancing, R_S, is less than 1·5.

Keywords: COVID-19, contact tracing, branching processes, SARS-CoV-2, testing strategy, case isolation, quarantine

1. Background

In December 2019, SARS-CoV-2, a novel coronavirus strain, was detected in Hubei Province, China.[1] By 31st January 2020 the first UK cases of COVID-19, the disease caused by the SARS-CoV-2, were confirmed.[2] Initial modelling studies indicated that fast and effective contact tracing could contain the UK outbreak in most settings.[3,4] However, by 20th March there were almost 4,000 confirmed cases nationwide,[5] at which point the UK Government halted national contact tracing and scaled up physical distancing measures, including the closure of schools and social venues, extending to heightened restrictions on non-essential travel, outdoor activities and between-household social mixing.[6]

By early May 2020 these measures were estimated to have reduced the effective reproduction number, R, from 2·6 to 0·62[7,8] and so from 12th-13th May in England some limitations on outdoor exercise were lifted and workers encouraged to return to work if they could maintain physical distancing.[9]

Capacity for diagnostic testing in the UK has been escalated over recent months, with capacity reaching over 100,000 tests a day by the end of April, with further plans in place to reach 200,000 tests a day by the end of

May.[10] Currently, testing of asymptomatic individuals is limited to workers and patients in NHS and social care facilities,[11] but from the 28th of May the UK Government rolled out the initial stages of their 'test & trace' contact tracing programme to the general population. This new approach was initiated with contact tracing of just over 2,000 confirmed cases. Crucially, the current strategy only tests symptomatic contacts and notifies individuals that they no longer need to isolate following a negative test. However, there are critical limitations to the diagnostic test, with poor sensitivity (current estimates imply close to 65%[12,13]), especially in community-based settings, leading to high false negative rates which are exacerbated by high variability in symptom severity.[13] Infectious individuals who test falsely negative may prematurely resume their normal activities, contributing to ongoing chains of transmission.

Imperfect adherence and the innate difficulties in identifying contacts will pose challenges for 'test & trace', particularly in crowded urban settings.[14] Therefore, evaluating both the limitations of contact tracing and how to maximise its effectiveness could be crucial in preventing a second peak in cases – which may overwhelm the NHS.[15] Additionally, if cases begin to rise exponentially, contact tracing capacity would be rapidly exceeded and stricter physical distancing measures required.

As our knowledge of the transmission dynamics of SARS-CoV-2 grows, extending Hellewell et al.'s[3] UK-focused contact tracing study with new insights could inform this 'test & trace' strategy. The key conclusion of the initial study was that highly effective contact tracing would be sufficient to control an initial outbreak of COVID-19 in the UK, however substantial new evidence supports much higher pre- and asymptomatic transmission rates than had initially been considered.[16,17,18] The focus on rapid testing in the UK contact tracing programme also requires a detailed assessment of the associated trade-offs through mechanistic modelling of the testing process. Up-to-date modelling studies are needed to investigate the feasibility of contact tracing and the conditions under which it is effective.

We use improved incubation period and serial interval estimates,[19,20] imperfect self-reporting and tracing rates, as well as simulating the use of diagnostic tests both for detection and tracing of asymptomatic infection chains. We also simulate decision-making regarding quarantine procedures for traced individuals, and then explore the trade-offs introduced by poor test sensitivity, particularly when negative test results are used to advise individuals to cease self-isolation.

2. Methods

In this extension of a previous COVID-19 branching process model,[3] the number of potential secondary cases generated by an index case and the exposure time for each case are drawn from Negative Binomial and Gamma distributions respectively. Secondary cases are averted if the primary case is in isolation at the time of infection, assuming within household segregation is possible. The probability of isolation depends on whether the primary case was traced, their test result, and adherence to self-isolation recommendations (Figure 1). Each simulation was seeded with five infected individuals that are undetected by the contact tracing system.

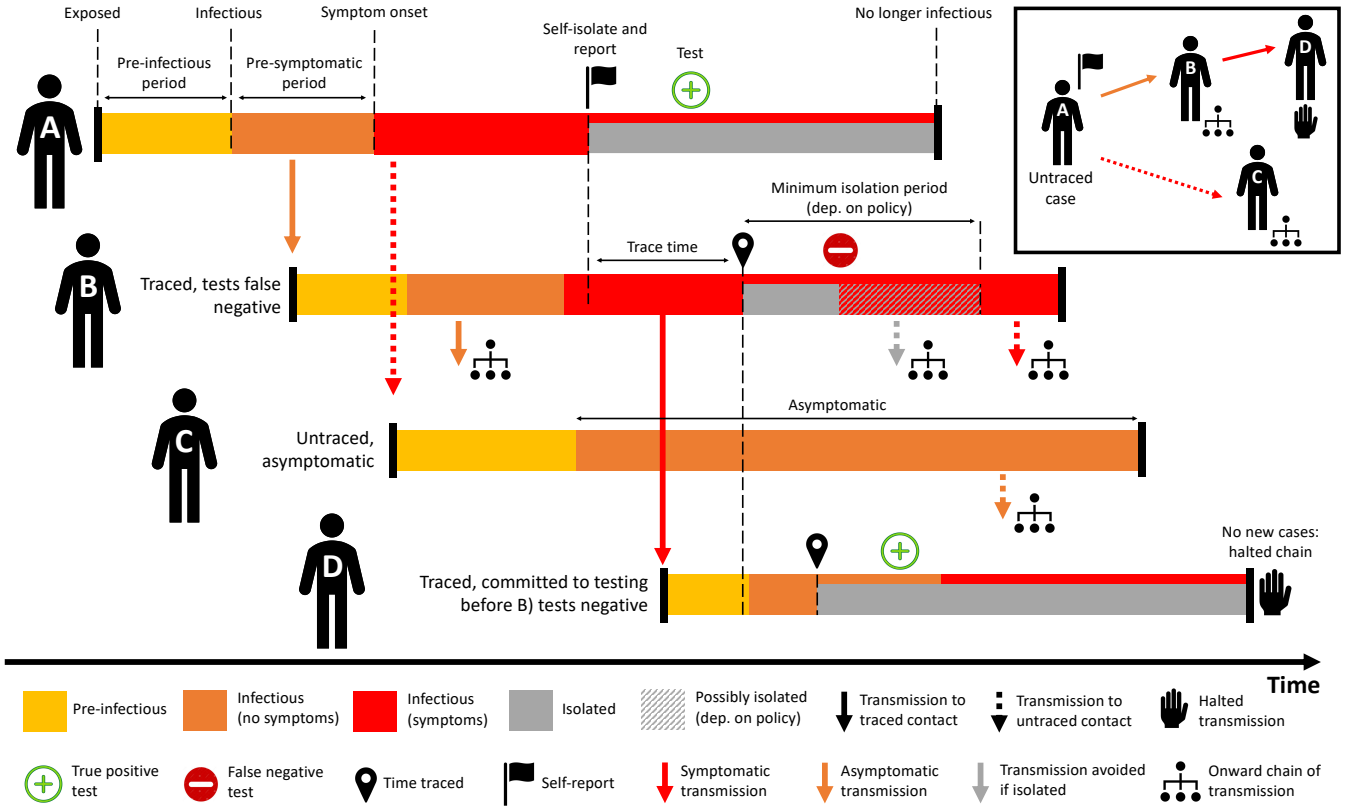

Figure 1: Overview of the contact tracing process implemented in our model. **Person A** isolates and self-reports to the contact tracing programme with some delay after symptom onset, by which time they have infected Persons B and C. When Person A self-reports contact tracing is initiated. They are then tested with positive result and remain isolated for their infectious period. **Person B** was infected by A prior to their symptom onset and is detected by tracing after some delay, after infecting Person D. After isolating they are tested, with a false negative result. This leads to B either a) stopping isolation immediately or b) finishing a minimum 7 day isolation period. Both may allow new onward transmission. **Person C** was infected by A but not traced as a contact. Person C does not develop symptoms but is infectious, leading to missed transmission. **Person D** was traced and tested before the false negative test was returned for Person B. The test for D returns positive, meaning that D remains isolated, halting this chain of transmission.

2.1. Secondary case distribution

A Negative Binomial distribution was chosen to represent heterogeneity in individual contact patterns or infectiousness, with the mean relating to the *effective reproduction number under physical distancing* R_S which takes a value of 1·1, 1·3 or 1·5 with a constant dispersion parameter $k = 0{\cdot}16$.[21] Here smaller k represents greater heterogeneity in transmission (as observed for SARS-CoV-2 in the absence of interventions). This results in the majority of index cases leading to no secondary infections, while a small proportion of individuals infect a large number of secondary cases. Parameter estimates and references can be found in Table 1.

Parameter	**Values**	**Refs**
Number of initial cases	5, 100	varied
Effective reproduction number under physical distancing, R_S	1·1, 1·3, 1·5	varied
Dispersion of R_S, k	0·16	[21,3]
Proportion asymptomatic	0·4	[16,17]
Delay: onset to isolation	1 day	fixed
Incubation period (Lognormal)	mean log: 1·43, sd log: 0·66	[19]
Infection time (Gamma)	shape: 2·12, rate: 0·69 day^{-1}	[19]
Infection time shift	-3 days	[19]
Untraced self-isolation prob.	90%	fixed
Self-reporting probability	0·1, 0·5, 1.0	varied
Contact tracing coverage (%)	40%, 60%, 80%, 100%	varied
Min time to trace contacts (days)	1 day	fixed
Max time to trace contacts (days)	1, 4 days	varied
Test sensitivity	0·65, 0·95	[13,12,22]
Delay: isolate to test result	0, 2 days	varied
Isolation duration if -ve test	0, 7 days	varied

Table 1: Model parameters values/ranges. Parameters taken from the literature are fixed and for other parameters a range of values are explored.

2.2. Infection profile

Each new case is infected at an exposure time drawn from a Gamma-distributed infectivity profile (shape = 2·12, rate = 0·69 day^{-1}) relative to three days before their infector's symptom onset, allowing for pre-symptomatic

transmission.[19] This exposure time is compared to the isolation times of the infector and cases are averted if the infector is in isolation when the infection event would have happened. For non-averted cases, symptom onset times are drawn from a Lognormal distribution (mean = 1·43, sd = 0·66)[19] and the probability of a case remaining asymptomatic throughout their infected period is fixed at 40%.[16,17] The full infection profile is shown in Figure 2.

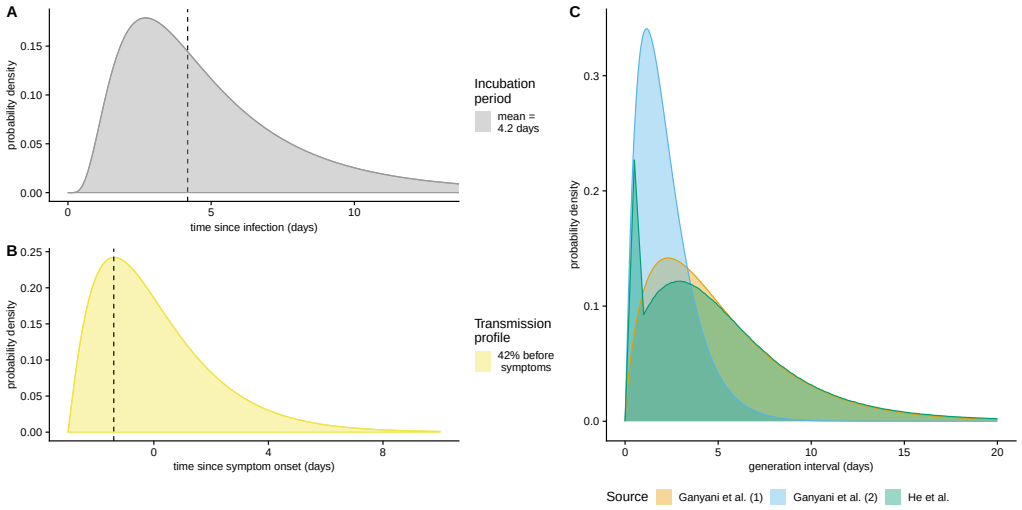

Figure 2: Parameter distributions for A: incubation period (infection time to symptom onset), B: transmission profile relative to symptom onset and C: generation interval. Distributions for A and B are taken from He et al.[19] and plot C shows the combined distribution this gives for the generation interval in green (the combined distribution is truncated below at 1 day) compared with Gamma-distributed intervals estimated by Ganyani et al. (blue and orange).[20]

2.3. Self-isolation

Untraced, symptomatic cases self-isolate one day after symptom onset with probability 90%, or otherwise continue with their normal behaviour. This adherence reflects the best case scenario, assuming high levels of public awareness. Our results could therefore be considered optimistic, however comparisons between scenarios still hold.

2.4. Contact tracing

Contact tracing is initiated by a symptomatic individual self-reporting, where an individual self-reports with a probability of 10% or 50%. The con-

tacts of that individual are then traced with 40%–100% coverage. If a contact is successfully traced they will always isolate. The time taken to trace and isolate a contact is either one day or drawn from a Uniform distribution of 1–4 days. In the absence of testing, traced contacts are assumed to isolate until non-infectious—approximately 14 days.[19] Any contacts that show symptoms or test positive will have their contacts traced; this continues until no further cases result in transmission chain extinction.

2.5. Testing

In simulations that include testing, we assume test sensitivities of 0·65 or 0·95 with the lower value representing true sensitivity observed in healthcare settings[12,13] and the higher value being closer to measurements in controlled conditions[22] and also to demonstrate utility of an alternative testing protocol with higher sensitivity. Due to the nature of the branching process model, only infected individuals are modelled so the test specificity is not relevant to transmission, although current specificity estimates are thought to be near 100%.[23]

When testing is included in the model, all individuals that either self-report to the contact tracing system (individual A in Figure 1), or are traced contacts (B & D in Figure 1), are tested. From the moment a contact self-reports or is traced, either a zero- or two-day delay is simulated before the test result is returned, chosen to be representative of UK programme targets. If a positive test is returned, the individual's contacts are traced. If a negative test is returned, two different scenarios are explored; either a)immediate release from quarantine, or b) individual is asked to complete a seven-day precautionary isolation period. Any contacts of a negative-testing case that were successfully identified prior to receiving the test result are still isolated and tested.

2.6. No active case detection

A scenario in which there is no active case detection in the community is considered whereby the only detected cases are those who are hospitalised. This is simulated by reducing the case reporting proportion to 0·06, reflecting the hospitalisation rate in the UK.[24] Time from symptom onset to hospitalisation is drawn from an Exponential distribution with mean 5·954 days (fitted to published data.[24]) We then defined the undetected outbreak size as the number of cases that were exposed prior to the first hospitalisation, given an

initial seeding of 5 index cases at $t = 0$. We also consider a special case of 100 index cases to represent a large super-spreading event.

2.7. Simulation process

Results presented are the combined output of 3,000 simulations for each parameter combination, or scenario, considered. These results are used to derive the probability of a large outbreak given a range of conditions. A *large outbreak* is considered to be 2,000 cases and each simulation is run for a maximum of 300 days. The threshold of 2,000 cases was chosen by running simulations with a maximum of 5,000 cases and noting that of the simulated epidemics that went extinct, 99% of extinction events occurred before reaching 2,000 cases. The model was written in `R` and the code is publicly available in an online GitHub repository (https://github.com/timcdlucas/ringbp).

3. Results

We found that where a test sensitivity of 65% was assumed, the impact of releasing individuals with false negative results from quarantine substantially undermined the positive impact of contact tracing. This is shown in Figure 3B, upper left panel, ($R_S = 1{\cdot}3$), where the probability of a large outbreak occurring is greater with an assumed test sensitivity of 65% compared to scenarios where no testing was carried out at all. This result was observed across all contact tracing coverage rates. The deleterious effect of releasing false negative cases is mitigated by using a precautionary seven-day quarantine period, which reduced the risk of a large outbreak from 27·2% to 15·3% for $R_S = 1{\cdot}5$, and from 12·6% to 2·7% for $R_S = 1{\cdot}3$, all with 80% contact tracing (Figure 3A).

The negative consequences of early quarantine cessation for false negative cases are further demonstrated by the fact that a two day delay in carrying out the tests also led to a decrease in the probability of a large outbreak, from 27·2% to 20·4% for R_S of 1·5 and 12·6% to 5·4% for R_S of 1·3. Combining the two-day delay in testing and the seven-day precautionary quarantine reduced the risk of a large outbreak further. The risk of a large outbreak was reduced from 27·2% to 13·1% for $R_S = 1{\cdot}5$ and from 12·6% to 1·9% for $R_S = 1{\cdot}3$, both with 80% contact tracing coverage.

In the case of instant testing and an immediate end to quarantine if the test is negative, there was a comparatively small benefit from scaling up of contact tracing coverage from 40% to 100%, implying that much of the

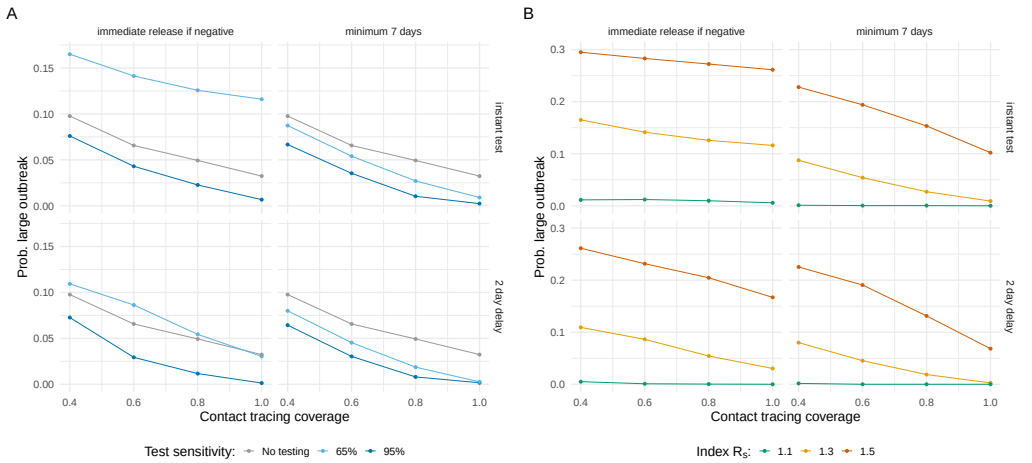

Figure 3: A: Comparing effectiveness of test-and-release of negative symptomatics (left-hand panels) with maintaining isolation of symptomatics for a minimum seven-day period (right-hand panels) given differing assumed values for R_S and accounting for delay to testing. Assuming 65% sensitivity of diagnostic 50% self-reporting. B: Comparing utility of test-and-release of negative symptomatics (left-hand panels) with maintaining isolation of symptomatics for a minimum of 7 days (right-hand panels) given assumed test sensitivities of 65% or 95%, and compared to no-testing. R_S is assumed to be 1·3.

potential positive impact of contact tracing could be lost if such an approach were taken.

Whilst a test with 65% sensitivity with no minimum quarantine period can undermine the benefits of contact tracing altogether, if a test were to be 95% sensitive, this would improve the outcome compared to no testing, reducing the probability of an outbreak from 4·9% to 2·5% (Figure 3). If there is a two-day delay before returning test results, a 65% test provides no clear benefit in terms of probability of a large outbreak. With a two-day test delay and seven-day precautionary quarantine a 65% sensitive test is almost as effective in reducing transmission as a 95% sensitive test because some asymptomatic chains of transmission are still identified while individuals with false negative tests generally remain in quarantine for the peak of their infectious period.

3.1. Limitations of contact tracing

To assess at what point during an epidemic contact tracing would be unable to control transmission, we looked at the probability of a large outbreak (greater than 2,000 cases within 300 days) given the current outbreak size (Figure 4A). Both the time taken to trace contacts and the proportion of contacts traced had effects on the risk of a large outbreak. With $R_S = 1{\cdot}3$ and a contact tracing coverage of 80% with a one day delay, the risk of a large outbreak increases almost linearly with total outbreak size (Figure 4A, top left). Once the number of cases reaches 250 the risk of a large outbreak is 24·1% and by 500 cases this increases to 36·8%. This is compared to the initial probability of 2·3% for these parameter values given 5 initial cases. With $R_S = 1{\cdot}5$ the risk of a large outbreak increased faster. At 250 cases the risk of a large outbreak is already 78·2% and by 500 cases it is 88·5%, compared to an initial risk of 15·5% when starting with 5 initial cases.

The time taken to trace cases had a stronger effect on the probability of a large outbreak when contact tracing coverage was higher (Supplementary Figure S1). With 80% contact tracing coverage, a four-day contact tracing delay increased the probability of a large outbreak, relative to a one day delay, from 13·1% to 17·3% for $R_S = 1{\cdot}5$ and from 1·9% to 4·0% for $R_S = 1{\cdot}3$.

Even with perfect contact tracing and exercising caution regarding test results (100% of contacts traced in 24 hours and a minimum quarantine period of 7 days) a large proportion of cases are likely to go unobserved (Figure 4B). High levels of symptomatic self-reporting to the tracing programme and improved test sensitivity can increase case detection: 95% sensitivity and 100% self-reporting gives an increase from 30·5% to 73·9% compared to 65% sensitivity and 50% self-reporting (both for $R_S = 1.3$). However, this still results in 26·1% of cases being missed, hence detecting every case is essentially infeasible.

Every missed case is a potential new chain of transmission and, given the low value of k, there is a risk of super-spreading events. To demonstrate this we consider a scenario where one missed case leads to a cluster of either 5 or 100 new cases in a population with poor adherence to self-reporting guidelines (Figure 4C and D respectively). We assume no self-reporting, so the first observation of the outbreak occurs when the first case is hospitalised, after which contact tracing may be initiated.

For a cluster of 5 new cases the median total outbreak size before the first case is hospitalised is 13 cases for $R_S = 1{\cdot}3$ and 18 cases for $R_S = 1{\cdot}5$, which translates to 4·1% and 30·1% probability of a large outbreak respectively if

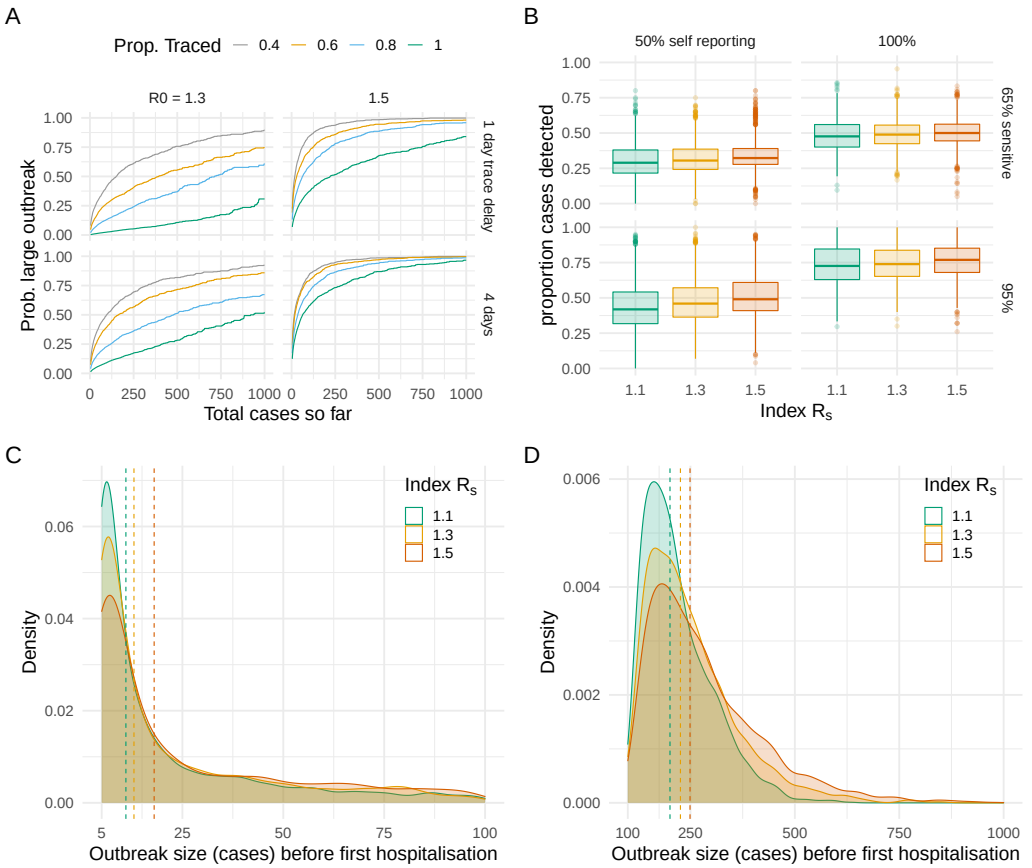

Figure 4: A) Comparing probability of outbreak by total number of cases so far. Sensitivity = 65%, self-reporting proportion = 0·5, individuals testing negative are isolated for a minimum of 7 days, time to test from isolation = 2 days. B) The proportion of cases detected with 100% contact trace and 50% or 100% self-reporting for 65% and 95% sensitivity tests. C) Total cases occurring before first hospitalisation in a population with no active tracing or case detection from one super-spreading event (5 new cases). D) Total cases occurring before first hospitalisation in a population with no active tracing or case detection from one super-spreading event (100 new cases).

80% contact tracing can be implemented (Figure 4A). For a cluster of 100 new cases the median total unobserved outbreak size is 226 for $R_S = 1{\cdot}3$ and 249 for $R_S = 1{\cdot}5$, translating to 22·6% and 78·0% probability of a large outbreak with 80% contact tracing. This emphasises the importance of maintaining physical distancing measures that restrict the size of indoor social gatherings

to avoid extreme super-spreading events which could rapidly escalate.

For $R_S = 1{\cdot}1$ there is a 5·37% chance of seeing at least 200 cases in all scenarios, even with slower tracing (up to four days' delay) and only 40% of contacts traced. Comparatively, for $R_S = 1{\cdot}3$ there is a greater than 5% chance of seeing 800 or more cases unless 100% contact tracing, or 80% contact tracing with a 1-day trace delay is achieved. For $R_S = 1{\cdot}5$ even 100% tracing with a one-day delay won't bring the probability of a large outbreak under 5%, but increasing tracing from 40% to 100% brings this probability down from 22·5% to 6·8%.

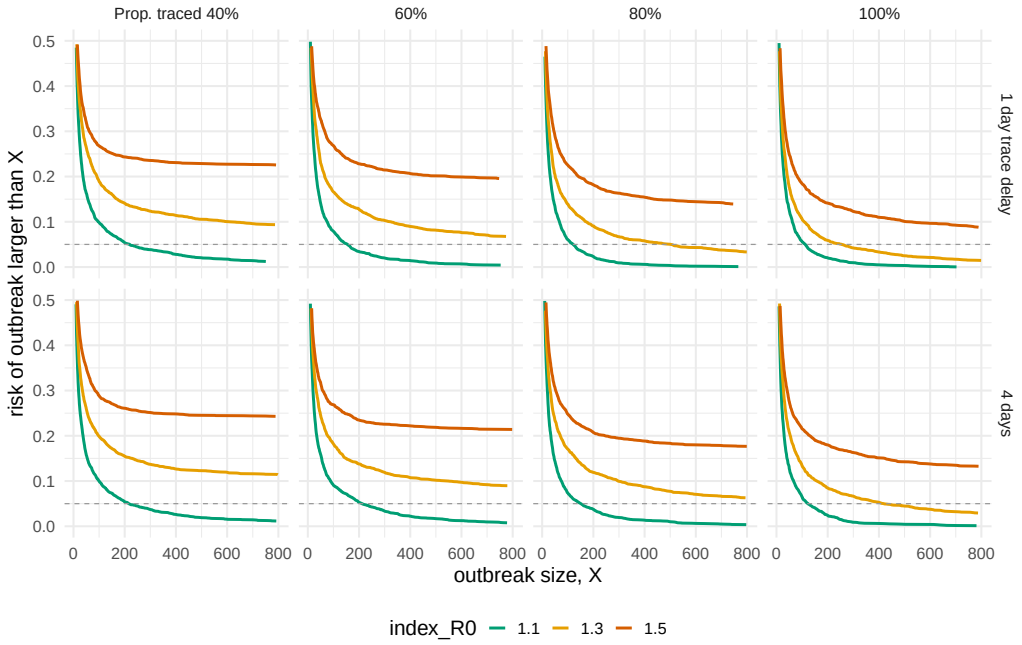

Figure 5: Outbreak size, with risk of exceeding that number of cases i.e. seeing an outbreak of at least that size for contact tracing coverages of 40% to 100% (left to right) and one or four days maximum trace delay (top to bottom). Grey dashed lines represent 5% risk of seeing an outbreak of at least that size.

3.2. Resource usage

We also found that higher contact tracing coverage results in a lower overall number of individuals which are traced, tested and quarantined, due

to the lower outbreak size (see Supplementary Figure S2). This means that achieving greater efficacy in tracing will ultimately require fewer resources. However, these resources are likely to be needed in a more condensed period of time.

4. Discussion

Our results show that with a test sensitivity of 65%, rapid testing which recommends infected but false-negative individuals to cease quarantine will be counter-productive, undermining contact tracing efforts, and sometimes being worse than not testing. However the impact of low test sensitivity could be mitigated by applying a minimum quarantine period to all traced contacts and using positive tests to prompt further contact tracing. This would allow negative individuals to leave quarantine comparatively early, but not immediately upon receipt of test result. Simply slowing down the decision-making process, so any false negative tests occur later in the infectious period, will also reduce the amount of transmission caused by premature cessation of quarantine and potentially increase likelihood of a more accurate test result.[13] Control policies in some countries are being designed to account for the high proportion of false negative individuals: for instance Greece requires negative testing international arrivals to self-quarantine for seven days;[25] in Singapore two negative tests 24 hours apart are required.[26]

We show that even a test with low (65%) sensitivity can improve contact tracing outcomes if the impact of false negative cases can be limited by employing appropriate precautionary measures. This effect is seen because testing can bridge asymptomatic links in transmission chains that would otherwise have been missed, although there is some uncertainty surrounding the infectiousness of asymptomatic individuals[19]. Nonetheless, this benefit is only possible if testing is applied to all contacts, not just those displaying symptoms as is the initial UK policy.

Testing asymptomatic contacts would require more testing and resources, as well as potentially testing individuals earlier in their infectious period, before symptom onset. Earlier testing increases the impact of immediate quarantine cessation for false negative cases, so this would require a minimum quarantine period. Despite these considerations, if very good contact tracing can be implemented from the beginning of the outbreak then fewer total resources will be required because of a smaller final outbreak size, meaning the key factor for feasibility will be time-limited resource access.

We demonstrated that small increases in the reproduction number under physical distancing measures, R_S, has a large impact on the feasibility of contact tracing. We only consider values of R_S up to 1·5, which is still substantially lower than estimates of R_0 in the absence of interventions ($R_0 \approx 2{\cdot}7$[27]) therefore, our estimates of R_S reflect a decrease in social contacts of almost 50% but even 80% coverage and a one day trace time still gives at least a 15% probability of a large outbreak. This reiterates that physical distancing is still vital, even with highly effective contact tracing, and that contact tracing will likely be insufficient to allow a complete return to normal life without additional measures, such as an effective vaccine.

In addition to general physical distancing, the risk posed by a single large super-spreading event means that relaxing restrictions on large gatherings, particularly indoors, could lead to a rise in case numbers. Even with very low $R_S = 1{\cdot}1$, a local cluster of 100 unobserved cases could approximately double in size before being detected, particularly if case detection is poor.

We found that large outbreak risk was minimal for $R_S = 1{\cdot}1$ no matter what the contact tracing and testing strategy. What is of note to national governments who are exiting lockdown is that a dramatic change in the dynamics occurs in the small absolute increase of R_S to 1·3. At $R_S = 1{\cdot}1$ with a poorly resourced or ineffective contact tracing system the probability of a large outbreak is roughly 1%. However only when $R_S \geq 1.3$ does an ineffective contact tracing system become noticeable, at which stage it is too late to act.

A number of our assumptions, particularly in comparison to the recently announced UK tracing strategy, may cause our results to appear unduly optimistic. For example, we model a scenario with very low initial case numbers and assume that tracing can occur before test results are received, and that contacts of up to 3 days pre-onset are traced. We also consider the test to have a blanket 65% sensitivity in all scenarios, whereas previous studies show that testing too early or late after exposure can dramatically increase false negative rates.[13] This means there is potentially an increased requirement for maintaining physical distancing measures, even if contact tracing is deployed at high coverage nationwide.

Furthermore there have been worrying developments in adherence to lockdown restrictions while we have developed this model. An unpublished study of 90,000 adults across the UK in the two weeks up to 25th May has found that adherence has dropped to 50%.[28] This may suggest that our assumption of 90% untraced symptomatic individuals self-isolating is at the upper end of

realistic, although symptomatic individuals will perhaps be more cautious. However, this could also have repercussions on assuming that contact-traced individuals will self-isolate when asked to do so, particularly asymptomatic individuals. Modelling studies in other countries have proposed combinations of contact tracing and population-level mitigation strategies[29] and a recent UK study puts R_S in the range of 1–1·6 for a combination of school closures, 50% reduction in social contacts and elderly shielding.[8] This covers the range of values considered in this study and demonstrates the potential level of physical distancing together with high-coverage contact tracing to keep the effective reproduction number below one.

Contact tracing improvements include *secondary contact tracing* seen in Vietnam, i.e. tracing the contacts of contacts of known cases, to get ahead of the chain of transmission.[30] An upcoming roll-out of a tracing app across the UK if combined with manual tracing could boost tracing coverage[31] and interactive dashboards are being rolled out across a number of countries to inform modelling efforts and raise public awareness.[32] Backwards contact tracing, whilst highly labour intensive, could also fill vital gaps where transmission links have been missed. As experience in contact tracing develops, it will also likely be possible to give contacts a prior probability of infection (based on the duration and setting of contact for example) and combine this with the test results to give a more accurate measure by which to determine isolation requirements.

Overall, we conclude that contact tracing could bring substantial benefits to controlling and preventing outbreaks, with tracing coverage and speed playing an important role, as well as testing. However, any 'test & trace' strategy must carefully consider the limitation of poor test sensitivity, as well as the additional tracing information obtained from testing asymptomatic individuals. Poorly sensitive tests are inappropriate for ruling out a diagnosis, and infectious individuals immediately halting quarantine following a false negative result could have dangerous implications. In line with previous studies, we have demonstrated that contact tracing alone is highly unlikely to prevent large outbreaks unless used in combination with evidence-based physical distancing measures, including restrictions on large gatherings.

5. CRediT contribution statement

Conceptualisation: ELD, TCDL, PK, GFM, TDH
Formal Analysis: ELD, TCDL

Funding acquisition: TDH
Investigation: ELD, TCDL, AB, TMP, LP, DA, TC
Methodology: ELD, TCDL
Software: ELD, TCDL, SA, JH
Visualization: ELD, AB
Writing – original draft: ELD, TCDL
Writing – review & editing: All authors

6. Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research in Context

Evidence before this study

Contact tracing, incorporating diagnostic testing, is a well-established method for controlling novel infectious disease outbreaks but has had variable success in restricting the spread of COVID-19. Modelling studies using early estimates of disease parameters, including Hellewell et al. and Keeling et al., suggested that these methods could be effective in controlling a UK outbreak of COVID-19, but rapidly increasing case numbers in March 2020 resulted in a focus on physical distancing measures. However, following declining cases throughout May 2020, the UK Government began easing physical distancing and rolled out a new 'test & trace' contact tracing programme. Initial methods appear to have disregarded the danger of false negative test results and miss the opportunity of using testing to identify asymptomatic chains of transmission.

Added value of this study

We incorporate testing and updated parameter estimates into an existing branching process model to assess how 'test & trace' programmes could be used to help control outbreaks of COVID-19. We find that if recent test sensitivity estimates (approx. 65%) are representative then using testing to rule-out cases and immediately revoke isolation advice could substantially reduce contact tracing efficacy. Additionally, even if these risks are mitigated, e.g. by introducing a minimum isolation period for all traced contacts, contact tracing must be used in combination with physical distancing measures to minimise risk of large outbreaks.

Implications of all the available evidence

Greater clarity in understanding of SARS-CoV-2 biology has allowed more targeted analysis of contact tracing feasibility for COVID-19 control. We find that success is highly dependent on targeting testing towards finding cases whilst minimising the impact of false negatives. Such methods should be used in combination with population-based measures, such as physical distancing. Future research considering the benefit of secondary contact tracing, and other methods for maximising tracing coverage or speed, could assess the value of enhancing current contact tracing methods.

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