Backwards contact tracing for COVID-19: analysis and review

Summary

- **Cases are often clustered:** backwards contacts are more than three times as likely to have infected new untraced cases.
- **Forward tracing will catch some backwards contacts:** 20% of backwards contacts will be captured by current forward tracing methods.
- **Modelling evidence:** a recent branching process study estimated bidirectional tracing could almost double effectiveness of contact tracing, but parameters are optimistic and the difference between the two methods will be lessened in practice by accidental capture of backwards contacts.
- **Repeat testing could be used to help classify direction of transmission:** immediate positive test could indicate backward; delayed positive likely to be forward.

Analysis

Backward contact tracing allows identification of clusters. Backwards contact tracing is being used in Japan to discover source cases and possible super-spreaders of COVID-19.[1] The number of new cases produced by one individual is highly dispersed (a small proportion of cases do the majority of the spreading; most people infect no one).[2] Backwards tracing allows identification of cases who have already infected one person, hence making it more likely they are part of a cluster. **For an R value of 1, a randomly selected infectious individual is only 21.3% likely to infect another person. However, if they have infected at least one person (i.e. they're a backwards contact) this increases to 66.5% (See Figure 1).**

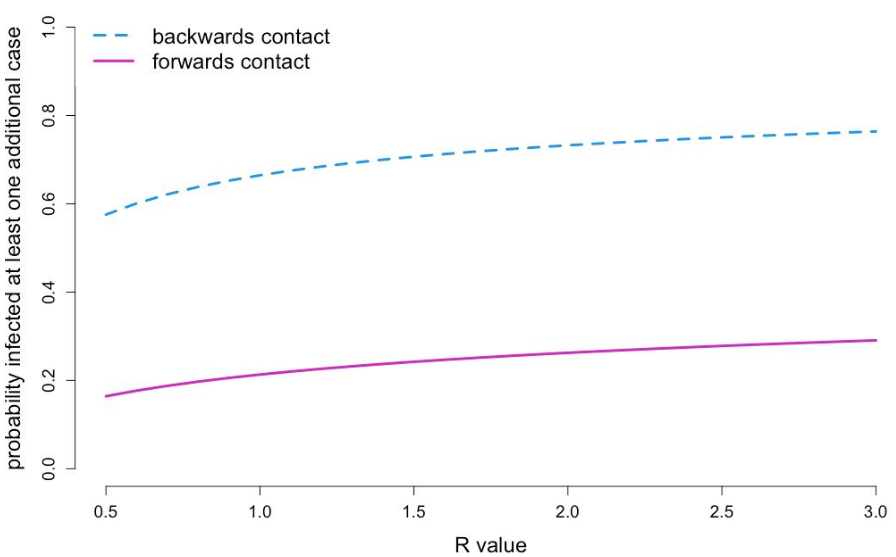

Figure 1: The probability an infectious individual will have infected at least one new untraced case given either: a) they are a forwards contact or self-reported case (purple, solid); or b) they are a backwards contact and hence we know they've infected at least one person (blue, dashed). R varied between 0.5 and 3, k=0.1.[3]

Forward tracing will catch some backwards contacts. The serial interval (time between infector and infectee showing symptoms) of COVID-19 is very short, sometimes negative due to high variability in symptom onset times,[4-6] so current contact tracing methods that consider contacts **up to 2 days pre-onset will already capture around 20% of backwards cases** (see Figure 2). If this period was extended to **6 days pre-onset then this could include 57-67%** of backward contacts, whereas **10 days would cover 83-90%**.

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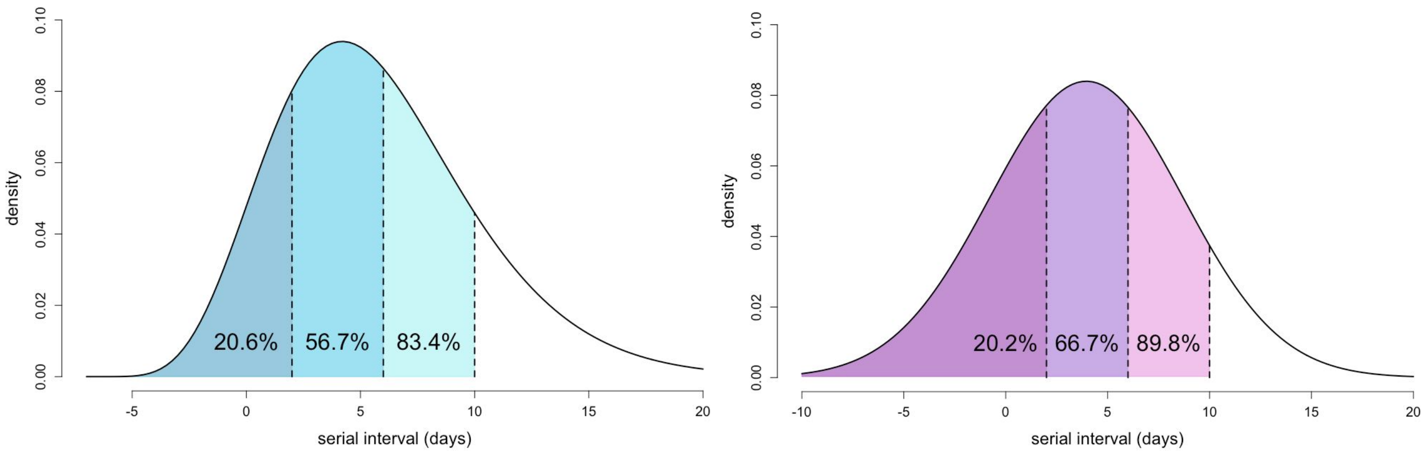

Figure 2: Proportion of backwards contacts captured by standard tracing methods for different time window sizes pre-onset for two different serial interval distribution assumptions. Shaded regions show the tracing window including up to 2, 6 and 10 days pre-onset. Left: Gamma distribution (He et al.)[4] Right: Normal distribution (Du et al., Ganyani et al.)[5,6]

Review of new modelling evidence

A recent preprint (Bradshaw et al.)[7] considering bidirectional contact tracing using a branching process model of COVID-19 transmission found that **bidirectional tracing performs consistently better than forward**, and for some small ranges of R_0 they found that bidirectional contact tracing keeps R_{eff} below one where forward tracing only does not. As the distinction between forwards and backwards is explicit in a branching process framework but will be less obvious in practice, leading to forwards-only tracing capturing at least 20% of backwards contacts, the difference is potentially smaller than represented. They also concluded that backwards tracing is *"required for reliable COVID control"*. However, this statement only applies to a high R_0 value (i.e. not social distancing) and very optimistic contact tracing parameters.

Important assumptions:

- Asymptomatic proportion = 45%; infectiousness (relative to symptomatic) = 50%
- Presymptomatic transmission = 48%
- Proportion of symptomatic cases that report to the programme = 90%
- Proportion of identified cases that share contacts = 98%
- Test sensitivity = 80%
- R_0 = 2.5, dispersion k = 0.11

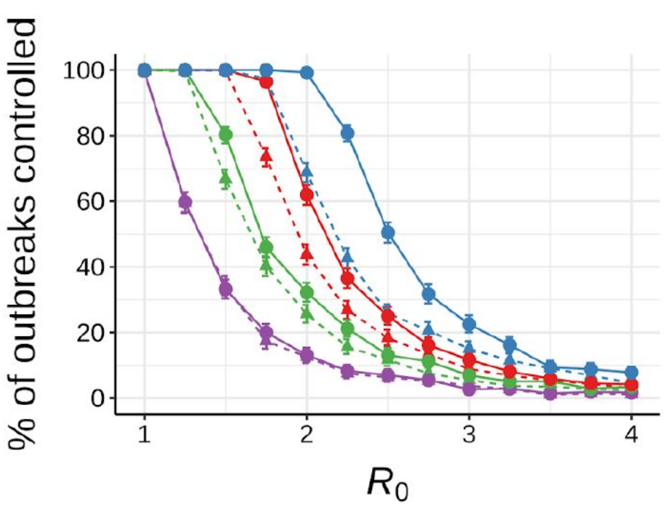

Figure 3: Comparing forward (triangles) and bidirectional (circles) tracing for manual (red), digital (green), manual + digital (blue) tracing and no tracing (purple). Taken from Bradshaw et al.[7] For a small range of R_0 values bidirectional contact tracing successfully controls COVID-19 while forwards only tracing does not (e.g. R_0 = 1.75 for manual tracing shown in red).

Implementation

Knowing the direction of transmission can be useful in determining isolation necessity, but also because it may potentially be worth putting more effort into tracing forward contacts of a case that is a known infector (i.e. backwards case) due to clustering. This topic was discussed in detail at a Newton Institute meeting on 8th June 2020 and repeat testing was recommended as a possible tool tool.

Suggestions:

- **Expand window pre-onset to include more backwards contacts (e.g. 7 days)**
- **Test and isolate all contacts immediately once identified.**
- **If positive then could be a backwards contact. Trace contacts and isolate household.**
- **If negative: wait until symptom-onset OR 7 days post-contact if no symptoms[8] and test again.**
    - **If negative this time then cease isolation.**
    - **If positive then isolate case and household and trace contacts.**

This will allow **identification of asymptomatic individuals** and **immediate tracing of forward chains** from potential backwards contacts. It will also **reduce the time true negative individuals must remain in quarantine** (max 7 days if contact on day of onset, min is 1 day if contact 1 week pre-onset). Repeat testing and informed timing of tests (e.g. 7 days post-exposure) will **maximise sensitivity**,[8] whilst 7 day isolation period will mean **false negatives stop isolating later in their infectious period,** when they are less likely to transmit. A 7 day pre-onset window will capture 65% of backwards cases (this will be higher if contacts are repeated). If R < 1 then the number of backwards cases will also be higher than the average number of forwards cases so backwards tracing has even higher relative benefit (see Figure 4).

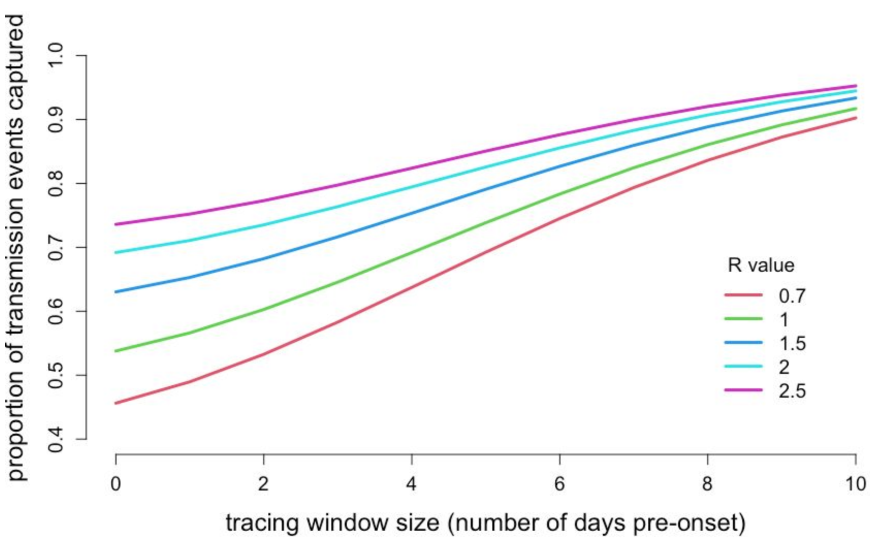

Figure 4: Proportion of directly linked cases (forwards and backwards) that could be found by increasing tracing window size. R value ranging from 0.7 (red) to 2.5 (purple).

References

1 - Oshitani, Hitoshi. "Cluster-based approach to Coronavirus Disease 2019 (COVID-19) response in Japan—February–April 2020."

2 - Jia, Jing, et al. "Epidemiological characteristics on the clustering nature of COVID-19 in Qingdao City, 2020: a descriptive analysis." *Disaster Medicine and Public Health Preparedness* (2020): 1-5.

3 - Endo, Akira, et al. "Estimating the overdispersion in COVID-19 transmission using outbreak sizes outside China." *Wellcome Open Research* 5.67 (2020): 67.

4 - He, Xi, et al. "Temporal dynamics in viral shedding and transmissibility of COVID-19." *Nature medicine* 26.5 (2020): 672-675.

5 - Du, Zhanwei, et al. "Serial Interval of COVID-19 among Publicly Reported Confirmed Cases." (2020).

6 - Ganyani, Tapiwa, et al. "Estimating the generation interval for coronavirus disease (COVID-19) based on symptom onset data, March 2020." *Eurosurveillance* 25.17 (2020): 2000257.

7 - Bradshaw, William J., et al. "Bidirectional contact tracing is required for reliable COVID-19 control." *medRxiv* (2020).

8 - Kucirka, Lauren M., et al. "Variation in False-Negative Rate of Reverse Transcriptase Polymerase Chain Reaction–Based SARS-CoV-2 Tests by Time Since Exposure." *Annals of Internal Medicine* (2020).

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