Estimating the risk of sustained community transmission of COVID-19 outside Mainland China

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Abstract

We use a global metapopulation transmission model to project the likelihood of observing sustained transmission of COVID-19 outside Mainland China. The model is calibrated on international case importation through January 23, 2020, and includes modeling travel restrictions within China and to and from international destinations. Under different scenarios concerning transmissibility reduction in China and levels of case ascertainment across countries, results suggest enough dispersion of undetected cases has occurred to seed global spread.

Methods

We project the likelihood of observing sustained community transmission and when of COVID-19 in various countries outside Mainland China. To model the international spread of the COVID-19 outbreak we use the Global Epidemic and Mobility Model (GLEAM), an individual-based, stochastic, and spatial epidemic model [2, 3, 9, 18]. The model generates an ensemble of possible epidemic scenarios described by the number of newly generated infections, times of disease arrival in each subpopulation, and the number of traveling infection carriers. We assume a starting date of the epidemic that falls between 11/15/2019 and 12/1/2019, with 40 cases caused by zoonotic exposure[14, 11]. The posterior distribution of the basic reproductive number $R_0$ is estimated by exploring the likelihood of importation of COVID-19 cases to international locations. To include the travel ban in Wuhan, we
implemented long-range travel restrictions beginning on January 23rd and decreased local commuting patterns starting on January 25, 2020. Travel limitations in China are modeled by using de-identified and aggregated domestic population movement data between Chinese provinces for February 2020 as derived from Baidu Location-Based Services (LBS). Starting early February 2020, more than 60 airline companies suspended or limited flights to Mainland China, and a number of countries including USA, Russia, Australia, and Italy have also imposed government issued travel restrictions [12, 7, 17, 15, 5, 16]. While it is difficult to calculate exactly the level of traffic reduction imposed by these measures we considered a 90% overall traffic reduction to and from Mainland China.

To project the future epidemic trajectory, we consider two scenarios concerning disease transmissibility in Mainland China:

- **Strong** reduction (50%) of the original transmissibility \( r = 0.50 \), from January 25 and onward.
- **Containment** situation corresponding to a relative transmissibility of \( r = 0.35 \) starting on February 5 and onward.

The relative reduction of transmissibility is assumed to be achieved through early detection and isolation of cases, mobility restrictions as well as behavioral changes and awareness of the disease in the population.

To estimate the seeding of the epidemic outside Mainland China, we have to assume the level of detection and isolation of imported cases in each country. Recently there have been several estimates for the rate of detection across countries, suggesting overall values in the range of 30% to 40% [8, 13, 4]. Here we use the classification proposed in Ref [8], stratifying countries in three groups; namely high, medium and low surveillance capacity according to the Global Health Security Index [1]. Here we report a baseline scenario where high, medium and low surveillance countries have a 40%, 20% and 10% detection rate. We report in the Appendix a high detection rate scenario where the values are 60%, 40% and 20% for high, medium and low surveillance capacity countries. In this latter scenario we also assume that surveillance captures locally generated cases at the same rate as imported cases, thus effectively lowering the reproductive number of the epidemic in each country proportionally.

**Results**

Assuming the detection rate defined for the baseline scenario and a generation time \( T_g = 7.5 \) days [10] the reproductive number in China before the implementation of control measures is estimated to be \( R_0 = 2.61 \) [90% CI 2.38-2.82] with a doubling time estimated at \( T_d = 4.5 \) days [90% CI (4.0-5.1)]. Details on the calibration of the model are reported in Ref [6]. The model is then used to simulate the evolution of the epidemic across the world according to the two transmissibility scenarios in China.

For each of the two transmissibility scenarios in Mainland China we performed more than 110,000 simulations and kept track of the local transmission in each country considered in the model. In Fig. [1] we report the model estimate of cases with local generation in
the reporting country as a function of time. On average we observe a general exponential increase in the number of cases locally generated. However as shown in the inset of Fig. 1 single realizations are more noisy and fluctuating. Note that we are not simulating reporting delays, and detection rates that may additionally increase the noise observed in the real-world epidemic curve.

![Figure 1: Daily median number of transmissions with local generation in the reporting country. The plot refers to the containment scenario in Mainland China and the baseline surveillance capacity. Error bar is the interquartile range (IQR) from simulations. In the inset we report the results from a single simulation.](image)

For each country we consider the probability that during any week after the beginning of the epidemic there are 50 cases or more per day that are locally generated. In Fig. 2 A we report results for countries in Asia that have already experienced importation of cases during January and February 2020. We show that even in the containment scenario for Mainland China, several countries exhibit a 50%, or larger, probability of sustained local transmission by mid March, 2020. In Fig. 3 A we report the same analysis for some selected European countries as well as the United States and Canada. The strong transmissibility reduction and the containment scenarios provide almost identical results. This suggests that the onset of local transmission is initially generated from importation from Mainland China, but after the issuing of travel restrictions the increase of local transmission is mostly driven from importation coming from other countries in Asia.

In Fig. 2B and Fig. 3B we show the probability that the total cumulative number of cases in each country falls within a given range for the containment scenario. From these plots we can see regional differences in the the timing of the epidemic. The subset of Asian countries exhibit at least a 50% probability of having more than 1000 cases by late March or April. This timing is earlier than that of the selected European and North American countries which show the same values by late April to May. We performed the same analysis in the high surveillance scenario and observe that sustained activity is hardly observed in any scenarios before the end of May (See Appendix). This indicates that surveillance is having a major role in preventing establishment of local transmission across the world.

These results were obtained under several assumptions. The first is that we use just a coarse three level characterization of high, intermediate and low surveillance capacity for countries[8]. We plan to include more refined analysis in future work. We are assuming that all cases can be potentially detected. This might not be the case for asymptomatic
infections. We are not considering the issuing of additional travel restrictions to and from countries that show sustained local transmission. All estimates do not consider the likely introduction of specific containment or mitigation policies issued to lower the transmissibility in specific countries that experience elevated epidemic activity. Finally, we are not considering superspreading events and differential transmissibility across age brackets. Even in the presence of these limitations we hope that the information provided here can be of help in assessing the risk of sustained community transmission of COVID-19 outside Mainland China.

Conclusions

Overall, the simulations suggest that even in a containment scenario of COVID-19 in Mainland China, if the detection rate of imported and locally generated cases by surveillance systems operates at the level of recent estimates, enough dispersion of undetected cases has occurred to seed global spread of the epidemic. We show numerically that to avoid the early onset of global epidemic, surveillance systems should operate with a detection rate higher than 60% for all imported and locally generated cases especially in the countries that have experienced the largest number of importations in the past months of the outbreak.
Figure 2: (A) Probability for the local generation of more than 50 infections per day in a specific week for different countries in Asia. The two scenarios considered represent disease containment and strong transmissibility reduction ($r = 0.50$). The black * symbols represent the first week where the probability is greater than 10%. The white x symbols represent the first week where the probability is greater than 50%. (B) Probability of generating a total number of infections in the logarithmic binned intervals by a specific week for the containment scenario. Intervals are inclusive on the left and exclusive on the right.
Figure 3: (A) Probability for the local generation of more than 50 infections per day in a specific week for different countries in North America and Europe. The two scenarios considered represent disease containment, and strong transmissibility reduction ($r = 0.50$). The black * symbols represent the first week where the probability is greater than 10%. The white x symbols represent the first week where the probability is greater than 50%. (B) Probability of generating a total number of infections in the logarithmic binned intervals by a specific week for the containment scenario. Intervals are inclusive on the left and exclusive on the right.
References


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Appendix: High detection scenario

Figure 4: (A) Probability for the local generation of more than 50 infections per day in a specific week for different countries in Asia. The two scenarios considered represent disease containment and strong transmissibility reduction ($r = 0.50$). The black * symbols represent the first week where the probability is greater than 10%. The white x symbols represent the first week where the probability is greater than 50%. (B) Probability of generating a total number of infections in the logarithmic binned intervals by a specific week for the containment scenario. Intervals are inclusive on the left and exclusive on the right.
Figure 5: (A) Probability for the local generation of more than 50 infections per day in a specific week for different countries in North America and Europe. The two scenarios considered represent disease containment, and strong transmissibility reduction ($r = 0.50$). The black * symbols represent the first week where the probability is greater than 10%. The white x symbols represent the first week where the probability is greater than 50%. (B) Probability of generating a total number of infections in the logarithmic binned intervals by a specific week for the containment scenario. Intervals are inclusive on the left and exclusive on the right.

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