Report 1: Estimating the potential total number of novel Coronavirus cases in Wuhan City, China

Natsuko Imai, Ilaria Dorigatti, Anne Cori, Steven Riley, Neil M. Ferguson

WHO Collaborating Centre for Infectious Disease Modelling
MRC Centre for Global Infectious Disease Analysis
Abdul Latif Jameel Institute for Disease and Emergency Analytics (J-IDEA)
Imperial College London

Correspondence: neil.ferguson@imperial.ac.uk ***V2 (updated to include second Thai case)***

Background

On the 31st December 2019, the World Health Organization (WHO) China Country Office was informed of cases of pneumonia of unknown aetiology in Wuhan City, Hubei Province, China [1]. A novel Coronavirus (2019-nCoV) related to the Middle Eastern Respiratory Syndrome virus and the Severe Acute Respiratory Syndrome virus has since been implicated [2].

As of 16th January 2020, 41 cases (including two deaths [3]) have been confirmed in Wuhan City with three confirmed cases in travellers detected in Thailand (2 cases) and Japan (1 case) [4–7]. Most cases have been epidemiologically linked to exposure at a seafood market in Wuhan which has been closed since 1 January 2020 in efforts to contain the outbreak. Although both travellers have a history of travel to Wuhan City, they did not visit the seafood market implicated in the other cases [2].

Using the number of cases detected outside China, it is possible (see Methods) to infer the number of clinically comparable cases within Wuhan City that may have occurred thus far.

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Summary

We estimate that a total of 1,723 cases of 2019-nCoV in Wuhan City (95% CI: 427 – 4,471) had onset of symptoms by 12th January 2020 (the last reported onset date of any case).

This estimate is based on the following assumptions:

- Wuhan International Airport has a catchment population of 19 million individuals [1].
- There is a mean 10-day delay between infection and detection, comprising a 5-6 day incubation period [8,9] and a 4-5 day delay from symptom onset to detection/hospitalisation of a case (the cases detected in Thailand and Japan were hospitalised 3 and 7 days after onset, respectively) [4,10].
- Total volume of international travel from Wuhan over the last two months has been 3,301 passengers per day. This estimate is derived from the 3,418 foreign passengers per day in the top 20 country destinations based on 2018 IATA data [11], and uses 2016 IATA data held by Imperial College to correct for the travel surge at Chinese New Year present in the latter data (which has not happened yet this year) and for travel to countries outside the top 20 destination list.

Caveats

1. We assume that outbound trip durations are long enough that an infected Wuhan resident travelling internationally will develop symptoms and be detected overseas, rather than being detected after returning to Wuhan. We also do not account for the fact that international visitors to Wuhan (such as the case who was detected in Japan) might be expected to have a shorter duration of exposure and thus a lower infection risk than residents. *Accounting for either factor correctly requires additional data but would increase our estimate of the total number of cases.*
2. We estimate the potential number of symptomatic cases with disease severity of a level requiring hospitalisation (both the cases detected in Thailand and Japan were moderately severe). Our estimates do not include cases with mild or no symptoms.
3. The incubation period of 2019-nCov is not known and has been approximated with the estimates obtained for MERS-CoV and SARS [8,9].
4. We assume that international travel is independent of the risk of exposure to 2019n-CoV or of infection status. If zoonotic exposure was biased towards wealthier people, travel frequency may be correlated with exposure. Also, some travel might be causally linked to infection status (to seek healthcare overseas) or the infection status of contacts in Wuhan (this may apply to the case detected in Japan) [10]. *Accounting for either association would increase the probability of a case travelling and therefore reduce our estimates of the total number of cases.*

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Sensitivity analysis

We explore the sensitivity of estimates of total cases to our assumptions about: i) the duration of the detection window (exploring a lower value of 8 days); ii) the catchment population size of Wuhan airport (assuming it might be 11 million, the population of Wuhan city [12], rather than 19 million, the population of the entire metropolitan area [1]); and iii) true exportations reported internationally (2, 3 and 4 cases). Table 1 summarises the baseline assumptions and alternative scenarios explored. We note that the currently reported number of cases (44) is substantially lower than the lower bound of our most conservative scenario (190 cases, Scenario 3).

Table 1: Estimated case numbers based on the baseline assumptions and alternative scenarios explored.

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Exported number of confirmed cases*	3	3	3	2	4
Daily international passengers travelling out of Wuhan International airport[1]	3,301	3,301	3,301	3,301	3,301
Effective catchment population of Wuhan airport	19 million	11 million	19 million	19 million	19 million
Detection window (days)	10 days	10 days	8 days	10 days	10 days
Estimated Total number of cases (95% CI)	1,723 (427 – 4,471)	996 (246 – 2,586)	2,155 (535 – 5,590)	1149 (190 – 3,549)	2,298 (712 – 5,341)

*reported number of confirmed cases detected internationally. [1]calculated from the 3 month totals reported by [11] corrected for the travel surge during Chinese New Year (see Summary).

Conclusions

It is likely that the Wuhan outbreak of a novel coronavirus has caused substantially more cases of moderate or severe respiratory illness than currently reported. The estimates presented here suggest surveillance should be expanded to include all hospitalised cases of pneumonia or severe respiratory disease in the Wuhan area and other well-connected Chinese cities. This analysis does not directly address transmission routes, but past experience with SARS and MERS-CoV outbreaks of similar scale suggests currently self-sustaining human-to-human transmission should not be ruled out.

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Methods

Using internationally reported cases, it is possible to infer the magnitude of comparable cases within Wuhan City that may have occurred thus far.

The total number of cases requiring healthcare is given by:

$$Total\ number\ of\ cases = \frac{number\ of\ cases\ detected\ overseas}{probability\ any\ one\ case\ will\ be\ detected\ overseas}$$

where the probability any one case will be detected overseas (p) is given by:

$$p = \ daily\ probability\ of\ international\ travel\ \times mean\ time\ to\ detection\ of\ a\ case$$

The daily probability of travel is calculated by:

$$daily\ probability\ of\ international\ travel = \frac{daily\ outbound\ international\ travellers\ from\ Wuhan}{catchement\ population\ of\ Wuhan\ airport}$$

Finally, the mean time to detection can be approximated by:

$$mean\ time\ to\ detection = incubation\ period + mean\ time\ from\ onset\ of\ symptoms\ to\ detection$$

Confidence intervals can be calculated from the observation that the *number of cases detected overseas*, *X*, is binomially distributed as Bin(*p*,*N*), where *p* = *probability any one case will be detected* overseas, and *N* is the *total number of cases*. *N* is therefore a negative binomially distributed function of *X.* The results in Table 1 are maximum likelihood estimates obtained using this negative binomial likelihood function.

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