Supplementary

The shortage of hospital beds for COVID-19 patients during the lockdown of Wuhan, China

Data sources

We retrieved daily numbers of laboratory-confirmed cases and deaths of SARS-CoV-2 infection from the daily reports of the National Health Commission of China (http://www.nhc.gov.cn/), for the period from January 17 to February 11, 2020 in Wuhan and 50 other cities in mainland China (*Xiaogan*, *Huanggang*, *Suizhou*, *Jingzhou*, *Xiangyang*, *Huangshi*, *Ezhou*, *Yichang*, *Jingmen*, *Xianning*, *Shiyan*, *Chongqing*, *Wenzhou*, *Xiantao*, *Shenzhen*, *Beijing*, *Guangzhou*, *Shanghai*, *Tianmen*, *Xinyang*, *Changsha*, *Nanchang*, *Enshi*, *Hangzhou*, *Ningbo*, *Hefei*, *Haerbin*, *Taizhou*, *Nanyang*, *Bengbu*, *Yueyang*, *Fuyang*, *Zhengzhou*, *Zhumadian*, *Chengdu*, *Shangrao*, *Xinyu*, *Xian*, *Tianjin*, *Jiujiang*, *Bozhou*, *Shaoyang*, *Qianjiang*, *Zhuhai*, *Shangqiu*, *Nanjing*, *Yichun*, *Anqing*, *Suzhou*, *Foshan*) (Figure S1). We did not use the data after February 12, 2020 because of changing diagnosis criteria, which caused an unusually dramatic increase in the number of confirmed cases(1). The officially reported numbers before January 17, 2020 have been criticized for serious underreporting(2), therefore we exported the data of early cases with onset dates from December 8, 2019 to January 3, 2020 from a recent study(3). These data were lagged for 14 days to account for the delay of symptom onset to laboratory test, and subsequently combined with the official data to replace the official data released before January 17, 2020 (Figure S2).

We also obtained daily population flow data from Wuhan to the selected cities from the Baidu migration database (https://qianxi.baidu.com/) during the Lunar New Year traffic rush periods: January 1 to February 28, 2019, and December 22, 2019 to February 17, 2020. The data after February 17 were not available at the time of analysis, so we extrapolated from the average population flow in the preceding 10 days.

The daily numbers of hospital beds designated for COVID-19 cases in Wuhan from January 23 to February 25, 2020 were retrieved from the published data and the official reports of the Wuhan Municipal Health Commission (WMHC),(4, 5) and the number was assumed to be unchanged after February 25, 2020. We also retrieved the proportion of inpatient beds in isolation wards for severe patients and ICU beds for critical patients, from the WMHC (5).

Mathematical modeling to estimate daily numbers of COVID-19 patients

We built a SEIR model to simulate the inter-city transmission of SARS-CoV-2 viruses driven by population inflow/outflow between the epicenter, Wuhan, and 50 other cities in mainland China. The structure of this SEIR model is as follows:

http://dx.doi.org/10.21037/atm-20-5248

$$
\begin{cases}
\vec{S}' = -\vec{S} * (\beta * G * \vec{J} + \frac{\vec{N}'}{\vec{N}}) \\
\vec{E}' = -\vec{E} * (\sigma + \frac{\vec{N}'}{\vec{N}}) + \vec{S} * (\beta * G * \vec{J} + \frac{\vec{N}'}{\vec{N}}) \\
\vec{I}' = -\vec{I} * (\gamma + \frac{\vec{N}'}{\vec{N}}) + \vec{E} * (\sigma + \frac{\vec{N}'}{\vec{N}}) \\
\vec{Z}' = \vec{I} * (\gamma + \frac{\vec{N}'}{\vec{N}}) - \vec{Z}/q \\
\vec{R}' = \vec{Z}/q \\
\vec{D}' = \vec{Z}/q * d \\
\vec{N}' = \vec{K}_{colsum} - \vec{K}_{rowsum} \\
\vec{C} = m * \gamma * \vec{I} \\
G = \left(1 - \frac{D_{Wuhan}}{N_{Wuhan}}\right)^{p} \\
\vec{J} = \left[\left(\frac{\vec{I}}{\vec{N}}\right) + \delta * \left(\frac{K}{\vec{N}}\right)^{T} * \left(\frac{\vec{I}}{\vec{N}}\right)\right]
\end{cases} \quad (1)
$$

In equation (1), $\vec{S}$ is the susceptible population in each city; $\vec{E}$ is the latent population; $\vec{I}$ is the currently infected population; $\vec{R}$ is the cumulative number of confirmed cases; $\vec{Z}$ denotes the post-symptom onset patients who were not admitted to hospital. $\vec{D}$ is the cumulative number of deaths from COVID-19 and D_{Wuhan} represents total number of deaths in Wuhan; $\vec{N}$ is the total population of each city and $\vec{N}'$ is the daily population change of each city; N_{Wuhan} is the current population in Wuhan; $\vec{C}$ is the daily officially reported cases in each city; and K_{ij} is a 51*51 matrix of daily population flow between city i and city j. Please note that K_{ij} changes with time and $K_{ii} = 0$; $\vec{K}_{rowsum/colsum}$ is the total population inflow/outflow of each city; $\vec{J}$ is the city-specific transmission rate adjustment of newly imported cases from other cities; δ is the transmission rate change during the transportation process; G represents the control measures other than traffic restrictions implemented since January 11, 2020, when the number of COVID-19 cases was officially reported to the public for the first time, and G is determined by public awareness of the epidemic, which is represented by the death rate in the epicenter.

We assumed that the lockdown and traffic restrictions had reduced 99% of the population flow from and within Wuhan since January 23, 2020. The daily number of diagnosed cases of SARS-CoV-2 infection in China was assumed to follow a Poisson distribution, as in equation $\vec{C}_{obs(t)} = \text{Poisson}(\vec{C}_t)$. $\vec{C}_{obs(t)}$ is the number of new cases reported in each city on day t, and $\vec{C}_t$ is the expected number of new cases reported on day t. Appendix Table 1 lists the range of key parameters assumed in the model.

Due to the overburdened healthcare system and limited laboratory testing capacity at the beginning of the outbreak, it is widely believed that COVID-19 cases were seriously underreported in the early stages of the outbreak in Wuhan. We therefore estimated the reporting rates according to previous studies (6-10): 1.8% on January 3, 3.0% on January 18, 14.0 % on January 23, 34.0% on February 8 and 35.3% on February 18 (Table 1). The daily report rates between these dates were interpolated by linear regression. We also considered the delay of laboratory tests from symptom onset in our model by adding a parameter, q, which was assumed to be roughly 14 days before January 17, and decreased this to q days on February 11 according to published epidemiological studies in Wuhan (11) (Figure S2). The length of delay between January

 http://dx.doi.org/10.21037/atm-20-5248

17 and February 11 was imputed by a linear regression. The parameter q in other cities outside Wuhan was fixed as q, which was same as the value in Wuhan on February 11, due to the relatively greater sufficiency of supplies in those cities.

$$l(\lambda) = \log \mathcal{L}(\lambda) = \sum_{i=1}^{k} \log f\left(\vec{N}, \vec{C}_{obs}, D_{obs\_Wuhan}, K_{ij}, \gamma, \sigma, \beta, m, q, d; I_0, \delta, p\right) \quad (2)$$

where $l(\cdot)$ is the total log-likelihood for the daily number of new cases and deaths; D_{obs_Wuhan} is the daily reported number of deaths; k is the total observation days. We estimated the parameters by using the maximum likelihood estimation approach with the likelihood framework (Table S4). The within-city transmission rate β was derived by the daily proportion of infectious individuals losing infectiousness multiplied by the basic reproduction number ($\beta = R_0 * \gamma$).

The 95% confidence interval (CI) of log-likelihood l was calculated from a Chi-square quantile and then 95% CI of individual parameters was calculated accordingly.

Estimation of hospital bed shortage for COVID-19 patients in Wuhan

The designated inpatient and ICU beds for mild, severe, and critical COVID-19 cases in Wuhan increased gradually from 1 766, 999 and 35 on January 23 to 28 739, 8 704, and 303 on 25 February 2020. In particular, two emergency hospitals, Huoshenshan and Leishenshan hospitals, were fully operational after February 10. Sixteen Fangcang shelter hospitals provided more than 10 000 beds for mild cases after February 20.(12) It is of note that the Fangcang shelter hospitals admitted only mild COVID-19 cases, but the designated hospitals and two emergency hospitals admitted mainly severe and critical cases as well as a small number of mild cases.

We built a simple model to simulate the occupancy of hospital beds designated for COVID-19 cases. Based on clinical and epidemiological studies, we assumed that 81%, 14%, and 5% of total cases were classified into mild, severe, and critical cases respectively.(13) The days of progression for severe and critical cases, as well as the length of stay in inpatient wards and ICUs, were obtained from two clinical studies.(14, 15) The length of hospital stay was assumed to follow a normal distribution, with means and standard deviations for mild, severe, and critical cases obtained from previous clinical studies.(14-16) We also assumed that severe cases had priority of admission over mild cases. The assumptions of disease progression probability and length of hospital stay for mild, severe and critical cases are summarized in Appendix Table 2. We also assumed that critical cases were admitted first, followed by severe cases, and that mild cases had the lowest priority. The following equations were used to evaluate the shortage of hospital beds for COVID-19 cases in Wuhan:

$$\begin{cases} P' = I_{new} - P_{admitted} \\ H' = P_{admitted} - P_{discharged} \\ H_T = \text{total number of patients admitted in day } T \\ P_T = \text{Shortage of hospital beds in day } T \end{cases} \quad (3)$$

Here H_T is the number of patients who were admitted to hospital on day T, with the maximum equal to the total number of beds on that day (Fangcang hospitals were included but only for mild cases). I_{new} is the daily number of new onset cases

 http://dx.doi.org/10.21037/atm-20-5248

estimated from the SEIR model in Equation (1). $P_{admitted}$ and $P_{discharged}$ are the daily numbers of patients newly admitted to and discharged from designated hospitals, respectively. P denotes the number of COVID-19 patients at the mild, severe and critical stages minus the total number of designated inpatient and ICU beds in day T, which is used to quantify the hospital bed shortage for COVID-19 patients. Then we simulate 1000 time to estimate the hospital bed shortage for mild, severe and critical cases. We obtained 95% Confidence interval by calculating 2.5% to 97.5% quantile of the estimated results. The median of the results is set as the estimation of hospital bed shortage.

Estimate of hospital bed shortage for non-COVID-19 patients in Wuhan

During the lockdown, most hospitals in Wuhan suspended non-emergency services due to a shortage of manpower and because many inpatient hospital beds were designated for COVID-19 patients. There are no official reports about the numbers of non-COVID-19 patients and hospital bed availability for them during the Wuhan lockdown. We proposed a simple model to estimate non-COVID-19 patients hospital bed shortages through social media posts. Appendix Table 3 presents the flowchart of the process of estimating hospital bed shortage for non-COVID-19. We retrieved all relevant posts before February 29 and found that the earliest date for such posts to appear was February 3 (17). We further deleted repeat posts from same Weibo users and narrowed down the search to Weibo users located in Wuhan to increase specificity. By screening the contents, we separated them into two groups: posts from those who mentioned they had confirmed and suspected SARS-CoV-2 infection, and posts from those who mentioned they did not have SARS-CoV-2 infection.

We first built a model to estimate the correlation between the hospital bed needs for mild, severe and critical cases of SARS-CoV-2 infection and the posts seeking help on the Weibo platform:

$$\begin{cases} P_{severe\ and\ critical} = P_{severe} + P_{critical} \\ W_{severe\ and\ critical} = \text{Binomial}\ (P_{severe\ and\ critical}, \zeta_{severe\ and\ critical}) \\ W_{mild} = \text{Binomial}\ (P_{mild}, \zeta_{mild}) \\ W_{total} * k = \mathrm{W}_{severe\ and\ critical} \\ W_{total} * (1-k) = \mathrm{W}_{mild} \end{cases} \quad (4)$$

Here we assumed that the probability that COVID-19 patients would have post messages related to their hospital bed demands, represented by ζ, followed a binomial distribution. P is the hospital bed shortage, and W_{mild} *and* $W_{severe\ and\ critical}$ represents the total number of posts by mild, severe and critical COVID-19 cases, respectively. k is the proportion of severe and critical cases in COVID-19 patients who posted social media messages seeking help. Specifically, the following equations were used to calculate ζ and k based on the estimates for COVID-19 patients from Equation (3):

$$l(\lambda) = \log \mathcal{L}(\lambda) = \sum_{i=1}^{3} \log f(\, W_i, P_{severe\ and\ critical}, P_{mild}; \zeta_{severe}, \zeta_{mild}, k). \quad (5)$$

where $l(\cdot)$ is the total log-likelihood for COVID-19 patients to post messages related to hospital beds on Weibo (Equation (4)). We estimated the parameters $\zeta_{severe}, \zeta_{mild}, k$ by using the maximum likelihood estimation approach with the likelihood

http://dx.doi.org/10.21037/atm-20-5248

framework.

Then we assumed three scenarios: 1) same proportions of patients with and without COVID-19 had posted messages on social media; 2) proportion of patients with and COVID-19 had posted messages on social media is 2 times as that of non-COVID-19 patients; 3) proportion of patients with and COVID-19 had posted messages on social media is 10 times as that of non-COVID-19 patients; so the daily ratio of hospital bed needs by COVID-19 patients to those by non-COVID-19 patients was estimated a quantitative relation to daily ratio of these two groups of posts.

In Equation (6), we further applied the estimated parameters $\zeta_{severe}, \zeta_{mild}, k$ to estimate the hospital bed shortage for non-COVID-19 patients:

$$l(\lambda) = \log \mathcal{L}(\lambda) = \sum_{i=1}^{3} \log f(W_i, \zeta_{severe}, \zeta_{mild}, k; P_{severe\ and\ critical}, P_{mild}). \quad (6)$$

where $l(\cdot)$ is the total log-likelihood for non-COVID-19 patients to post messages related to hospital beds on Weibo (Equation (4)) and the 95% confidence intervals (CI) based on a Chi-square quantile. We estimated the parameters $P_{severe\ and\ critical}, P_{mild}$ and 95% CI by using the maximum likelihood estimation approach, to calculate the hospital bed shortage for severe and mild cases of non-COVID-19 patients.

Because the earliest post about hospital bed shortages appeared on February 3 and most hospitals in Wuhan gradually resumed normal services in early March, we calculated the hospital bed shortage for non-COVID-19 patients for February 2020 only. We separated daily estimates into three periods due to the greatly increased number of designated hospital beds on February 10 and on February 20 (Figure 2). We expected the relative likelihood of patients posting messages between mild, severe/critical COVID-19 cases to be different across these three periods. In equation (5), i denotes three periods: February 3-10, when there was a serious shortage of designated beds; February 11-20, when the most severe cases were admitted; and February 21-29, when bed vacancies gradually increased.

Simulation scenarios

The Wuhan lockdown since January 23 dramatically reduced the volume of intra-city traffic (99% reduction in our assumption). However, most countries/cities outside China adopted less stringent traffic restrictions, and home quarantine was voluntary. Hence the traffic volume reduction was probably much lower than 99%. To compare, we simulated three additional scenarios: decrease of traffic volume by 80% and 50%, and no traffic restriction (0%). In addition, the Wuhan lockdown was implemented in the stage of exponential growth of this outbreak, therefore it would be interesting to examine the predicted efficacy of an earlier enforcement on January 3 and later implementation on February 12 (20 days earlier/later than the actual implementation date). We simulated the transmission of SARS-CoV-2 infection under these different scenarios, calculating the cumulative number of cases by February 11, 2020 and the final epidemic size of the first wave. We quantified the relative efficiency of traffic restriction levels and timing by comparing these estimates to the estimated cumulative cases of real scenarios in Wuhan and 50 cities outside of Wuhan. We also estimated the hospital bed shortage in Wuhan under these scenarios.

 http://dx.doi.org/10.21037/atm-20-5248

The experience of the 2009 influenza pandemic suggested that infection control measures and human behavior changes could interrupt the rapid spread of novel viruses, but the gradual relaxing of these measures could result in multiple waves of epidemics over months or years(18-20). Similarly, during the lockdown, aggressive social distancing measures and traffic restrictions could gradually wane as well. Hence we also investigated the possibility of a second wave based on different waning levels of these personal mitigation measures in Wuhan. We replaced G in equation (1) by the following equation to forecast the second wave:

$$\begin{cases} G = \left(1 - \frac{D^{*}{}_{\text{Wuhan}}}{N_{\text{Wuhan}}}\right)^{p} \\ D^{*'}{}_{\text{Wuhan}} = q * \vec{Z}_{Wuhan} \times d - \varepsilon \times D_{Wuhan} \end{cases} . \quad (6)$$

where ε is the waning weight of control measures (for example, $\varepsilon = \frac{1}{30}$ if social distancing measures were sustained for 30 days after 11 February 2020). To simplify the calculation, we did not consider cases imported from overseas in our model, since strict border controls and quarantine measures were in place and all travelers from overseas were required to take laboratory tests for SARS-CoV-2 (21).

References

1. National Health Commission of Hubei province. Situation report of the pneumonia cases caused by the novel coronavirus (in Chinese) http://wjw.hubei.gov.cn/bmdt/ztzl/fkxxgzbdgrfyyq/xxfb/202002/t20200213_2025580.shtml, 12 February 2020.
2. Zhao S, Musa SS, Lin Q, et al. Estimating the Unreported Number of Novel Coronavirus (2019-nCoV) Cases in China in the First Half of January 2020: A Data-Driven Modelling Analysis of the Early Outbreak. J Clin Med. 2020;9(2).
3. Zhu N, Zhang D, Wang W, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020.
4. Li J, Yuan P, Heffernan J, et al. Observation wards and control of the transmission of COVID-19 in Wuhan. Bull World Health Organ. 2020.
5. Wuhan Municipal Health Commission (WMHC) [Available from: http://wjw.wuhan.gov.cn/.
6. Verity R, Okell LC, Dorigatti I, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. The Lancet Infectious Diseases. 2020;20(6):669-77.
7. Wang C, Liu L, Hao X, et al. Evolving Epidemiology and Impact of Non-pharmaceutical Interventions on the Outbreak of Coronavirus Disease 2019 in Wuhan, China. medRxiv. 2020:2020.03.03.20030593.
8. Wu JT, Leung K, Bushman M, et al. Estimating clinical severity of COVID-19 from the transmission dynamics in Wuhan, China. Nature Medicine. 2020;26(4):506-10.
9. Imai N, Dorigatti I, Cori A, et al. Report 2: Estimating the potential total number of novel Coronavirus cases in Wuhan City, China. 2020.
10. Li R, Pei S, Chen B, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). Science. 2020;368(6490):489.
11. Pan A, Liu L, Wang C, et al. Association of Public Health Interventions With the Epidemiology of the COVID-19 Outbreak in Wuhan, China. JAMA. 2020.
12. Chen S, Zhang Z, Yang J, et al. Fangcang shelter hospitals: a novel concept for responding to public health emergencies. The

Lancet. 2020.

13. Wu Z, McGoogan JM. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72 314 Cases From the Chinese Center for Disease Control and Prevention. JAMA. 2020;323(13):1239-42.
14. Guan WJ, Ni ZY, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med. 2020.
15. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020.
16. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet. 2020;395(10229):1054-62.
17. wuhancrisis, hanfu. Help seeking posts on Weibo platform: GitHub repository; 2020 [Available from: https://github.com/wuhancrisis/wuhancrisis.github.io.
18. Poletti P, Ajelli M, Merler S. The effect of risk perception on the 2009 H1N1 pandemic influenza dynamics. PLoS ONE. 2011;6(2):e16460.
19. Wessel L, Hua Y, Wu J, et al. Public health interventions for epidemics: implications for multiple infection waves. BMC Public Health. 2011;11 Suppl 1:S2.
20. He D, Dushoff J, Day T, et al. Inferring the causes of the three waves of the 1918 influenza pandemic in England and Wales. Proc Biol Sci. 2013;280(1766):20131345.
21. Press conference on March 23, 2020 (in Chinese) [Available from: http://www.nhc.gov.cn/xcs/fkdt/202003/7f61fbea461846ba889c6cf7766a8e16.shtml.
22. Wu JT, Leung K, Leung GM. Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. The Lancet. 2020;395(10225):689-97.
23. Lin Q, Zhao S, Gao D, et al. A conceptual model for the coronavirus disease 2019 (COVID-19) outbreak in Wuhan, China with individual reaction and governmental action. Int J Infect Dis. 2020;93:211-6.
24. Guan W-j, Ni Z-y, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. New England Journal of Medicine. 2020;382(18):1708-20.
25. Yang S, Cao P, Du P, et al. Early estimation of the case fatality rate of COVID-19 in mainland China: a data-driven analysis. Ann Transl Med. 2020;8(4):128-.
26. Wang D, Hu B, Hu C, et al. Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus–Infected Pneumonia in Wuhan, China. JAMA. 2020;323(11):1061-9.
27. Mizumoto K, Kagaya K, Chowell G. Early epidemiological assessment of the transmission potential and virulence of coronavirus disease 2019 (COVID-19) in Wuhan City, China, January–February, 2020. BMC Medicine. 2020;18(1):217.
28. National Health Commission of the People’s Republic of China. Situation report of the pneumonia cases caused by the novel coronavirus (in Chinese) http://wjw.wuhan.gov.cn/ztzl_28/fk/yqtb/, 23 January 2020.

http://dx.doi.org/10.21037/atm-20-5248

Table S1 Parameter descriptions and a prior value (or range) assumed or adopted from references

Parameter	Description	Value (range)	Sources
q_{Wuhan_early}	test delay in Wuhan before 17 January (in days)	14	Assumed
q	test delay in Wuhan on 11 February (in days) and other cities outside Wuhan (in days)	(1,3)	Assumed*
R_0	reproduction number of SARS-CoV-2	(2.3, 3)	Reference (22)*
β	within-city transmission rate	R_0* γ	Calculated
γ	rate of infectious individuals losing infectiousness per day	(0.13, 0.3)	Reference (22, 23)*
I_0	initial number of infected patients at day zero in Wuhan (22 Dec. 2020)	(1,100)	Assumed*
σ	rate of exposed individuals showing infectiousness per day	(0.14, 0.5)	Reference (24)*
p	intensity of social distancing measures by the government and individuals	(0, 15000)	Assumed*
δ	transmission rate adjustment during transportation process	(0, 30)	Assumed*
d	crude case-fatality-ratio	4.5%	Reference (25-27)

* parameter needs to be estimated within a given range

Table S2 The assumptions of disease progression probability and length of hospital stay (days) for mild, severe and critical cases

	stage1: mild	stage2: severe	stage3: critical	stage4: severe	percentage of total cases
Critical cases (survive)	6	5.5	6.5	3	3.6%
Critical cases (dead)	6	5	7.5	0	1.4%
Severe cases	6	7	0	0	14.0%
Mild cases	11	0	0	0	81.0%

Table S3 Steps of estimating hospital bed shortages for non-COVID-19 patients

Stage	Process
1	Screened the contents, separated them into two groups: posts from those who mentioned they had confirmed and suspected SARS-CoV-2 infection, and posts from those who mentioned they did not have SARS-CoV-2 infection.
2	Based on our previous estimates for COVID-19 patients, calculated the probability, , that COVID-19 patients would post messages and the proportion k of severe and critical cases in COVID-19 patients who posted social media messages seeking help.
3	Applied the estimated parameters, and k, to estimate the hospital bed shortage for non-COVID-19 patients by using the maximum likelihood estimation approach with the likelihood framework.

 http://dx.doi.org/10.21037/atm-20-5248

Table S4 Maximum likelihood estimates and 95% CI of parameters estimated from the model

Parameter	Estimate	95% CI
R_0	2.92	(3.00, 2.70)
γ	0.24	(0.23, 0.27)
I_0	23	(16, 28)
σ	0.48	(0.43, 0.49)
p	13 200	(12 300, 14 700)
δ	4	(3,5)
q	2.81	(2.41, 2.91)

Table S5 Estimated hospital bed shortages for COVID-19 patients

N (95% confidence interval)	Hospital bed shortage for mild COVID-19 cases			Hospital bed shortage for severe COVID-19 cases			Hospital bed shortage for critical COVID-19 cases		
Time period	February 1 – 10	February 11 – 20	February 21 – 29	February 1 – 10	February 11 – 20	February 21 – 29	February 1 – 10	February 11 – 20	February 21 – 29
Current scenario	41241 (32852, 49797)	18238 (13824, 23100)	0 (0, 92)	1498 (553, 2563)	1553 (451, 3072)	0 (0, 0)	160 (108, 215)	143 (100, 187)	39 (16, 69)
Restricted on 5 February	43531 (34238, 52874)	24576 (18952, 30452)	341 (0, 1124)	1450 (502, 2639)	2242 (744, 3985)	0 (0, 241)	163 (110, 220)	169 (122, 218)	59 (28, 92)
Restricted on 11 January	48435 (38622, 58508)	23668 (18202, 29141)	119 (0, 574)	2119 (939, 3398)	3143 (1417, 4965)	31 (0, 407)	186 (126, 250)	172 (124, 223)	52 (23, 84)
Restricted 80% of traffic	41794 (32989, 50576)	19384 (14290, 24643)	0 (0, 188)	1513 (519, 2652)	1703 (484, 3333)	0 (0, 38)	162 (109, 219)	147 (104, 194)	43 (17, 73)
Restricted 50% of traffic	42312 (33459, 51056)	21195 (16160, 26289)	55 (0, 467)	1501 (526, 2576)	1855 (575, 3444)	0 (0, 67)	162 (109, 220)	155 (111, 202)	48 (21, 82)
no restriction	43341 (34560, 52205)	24616 (18716, 30447)	397 (0, 1231)	1463 (540, 2589)	2190 (804, 3924)	0 (0, 241)	163 (111, 220)	168 (122, 217)	59 (29, 93)

http://dx.doi.org/10.21037/atm-20-5248

Table S6 Estimated hospital bed shortages for non-COVID-19 patients

N (95% confidence interval)	February 3 – 10 *			February 11 – 20			February 21 – 29		
Weight of non-COVID-19 patients send posts compare to COVID-19 patients	1	0.5	0.1	1	0.5	0.1	1	0.5	0.1
Estimated hospital bed shortage for severe non-COVID-19 patients	13 (1, 336)	26 (3, 675)	126 (15, 3408)	26 (2, 298)	51 (5, 601)	252 (25, 3 022)	13 (1, 336)	26 (3, 675)	126 (15, 3408)
Estimated hospital bed shortage for mild non-COVID-19 patients	919 (63, 5087)	1838 (127, 10177)	9 187 (639, 50899)	1 838 (371, 7166)	3 675 (743, 14336)	18 373 (3714, 71694)	919 (63, 5087)	1 838 (127, 10177)	9187 (639, 50899)

*Estimations start from 3 February, since the earliest post to the Weibo platform was on 3 February.

Table S7 Estimated daily hospital bed shortage for COVID-19 cases in the second wave in Wuhan

Waning weight	1/30	1/40
Onset of the second wave	late-June	early-August
Maximum shortage for critical cases (95% CI)	66 (27, 111)	53 (9, 92)
Maximum shortage for serve cases (95% CI)	0 (0, 0)	0 (0, 0)
Maximum shortage for mild cases (95% CI)	0 (0, 0)	0 (0, 0)

http://dx.doi.org/10.21037/atm-20-5248

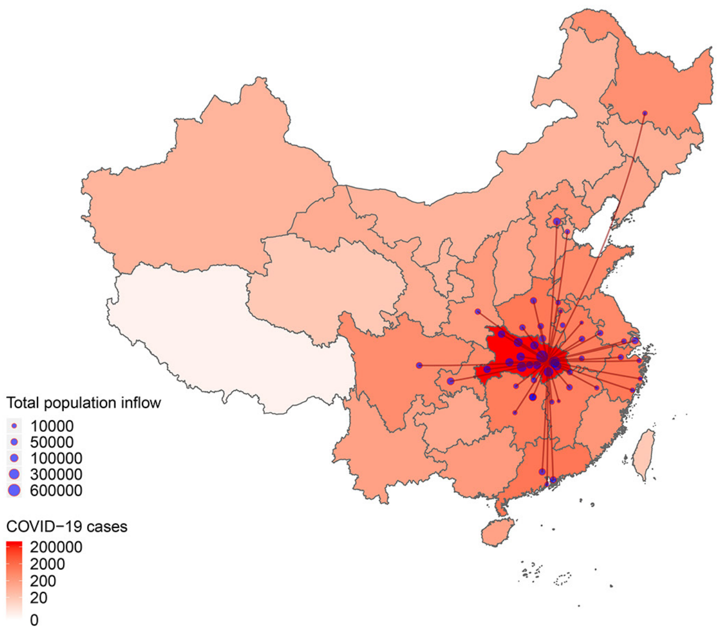

Figure S1 Cumulative numbers of COVID-19 cases in China as of 11 February 2020. Red lines show population flow between Wuhan and 50 other cities. The diameter of the blue points presents levels of total outflow from Wuhan to those cities from December 22, 2019 to January 23, 2020.

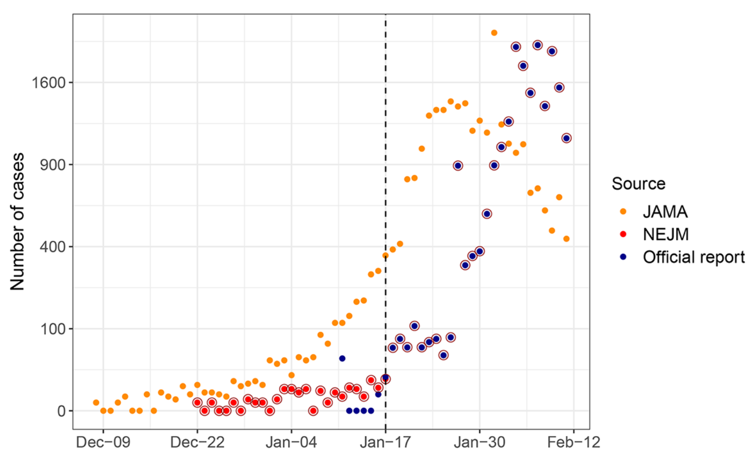

Figure S2 Daily numbers of new COVID-19 cases by diagnosis date (brown circles) used in this study to fit the model. The data were combined from the published data of early cases (red dots) from reference (3) (lagged for 14 days to account for the delay between symptom onset and laboratory testing) and officially reported numbers (blue dots) (28). Orange dots are number of onset cases (13).

 http://dx.doi.org/10.21037/atm-20-5248

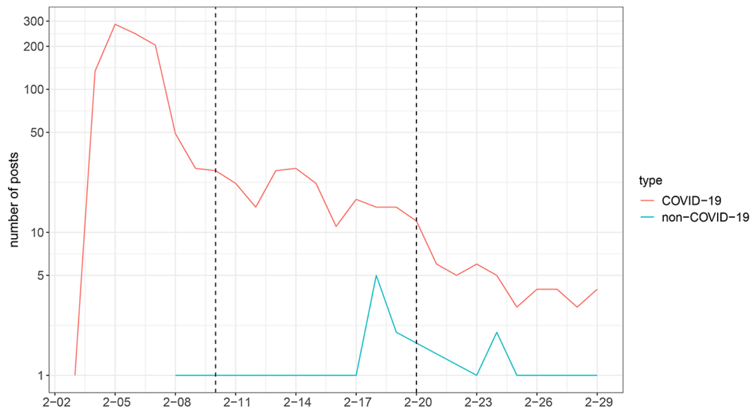

Figure S3 Daily numbers of different types of social media messages posted by the Wuhan users to the Weibo, seeking online medical consultations or complaining about limited hospital beds or the suspension of healthcare services.

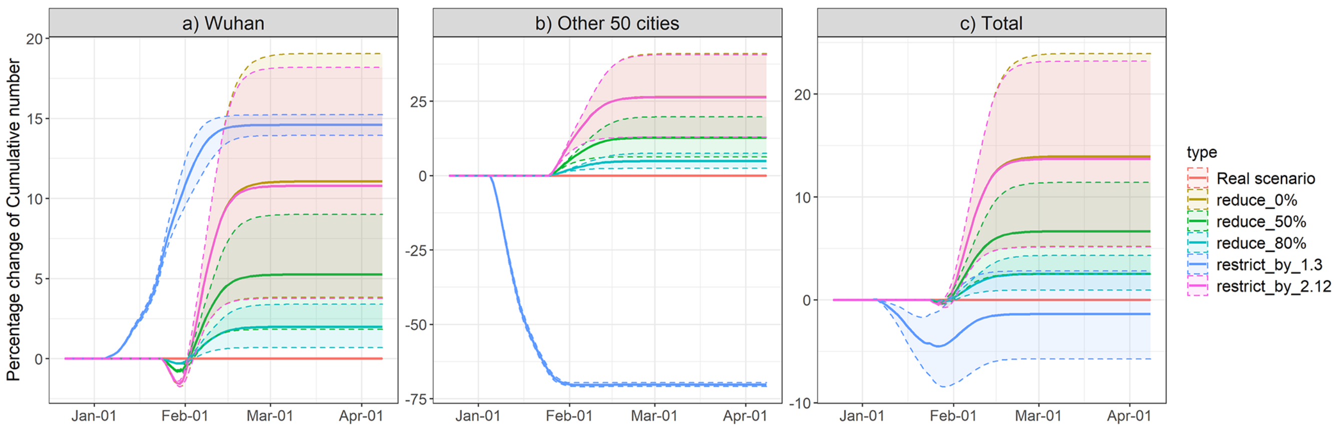

Figure S4 Prospective evaluation of the traffic restriction policy under different scenarios by April 8, 2020. (a) relative change of total cumulative cases in Wuhan with 95% confidence intervals; (b) relative change of total cumulative cases in 50 cities (excluding Wuhan) with 95% confidence intervals; (c) relative change of total cumulative cases in all cities with 95% confidence intervals. We considered the current policy, which reduced traffic volume by 99% (red), together with five other scenarios: traffic volume reduced by 80% (cyan), by 50% (green), and no traffic restrictions (brown), as well as traffic restrictions implemented on January 3, 2020 (blue) and February 12, 2020 (pink).

 http://dx.doi.org/10.21037/atm-20-5248

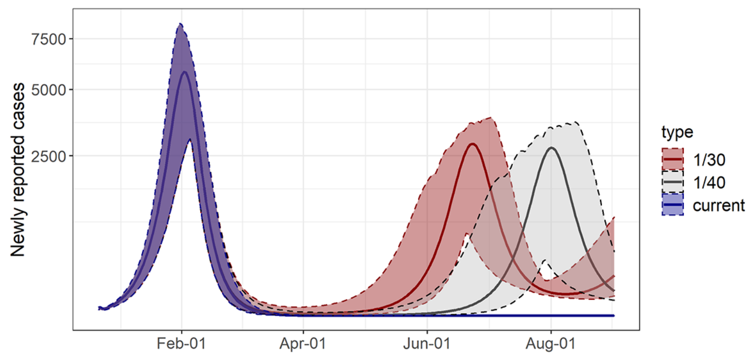

Figure S5 Possible multiple infection waves analysis. Forecast of the effect on newly reported cases with 95% confidence intervals by July 1, 2020, under different public and government reaction waning weights.

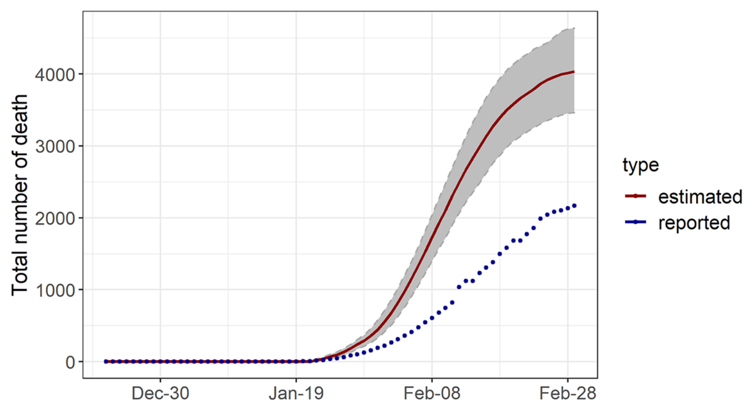

Figure S6 Daily numbers of reported COVID-19 death cases (blue lines) and estimated death cases (red lines) with 95% confidence intervals (gray bar), 22 December 2019 to 29 February 2020, Wuhan.

 http://dx.doi.org/10.21037/atm-20-5248