Modelling the epidemic trend of the 2019-nCOV outbreak in Hubei Province, China

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Abstract

As of 8am 30th January (Beijing Time) 2020, Approximate 8000 cases across the world have been confirmed. It's necessary to simulate epidemic trend of the 2019-nCOV outbreak in Hubei Province, the hardest-hit area. By SEIR simulation, the predicted epidemic peak in Hubei will be within 28th January 2020 to 7th February 2020, up to 7000-9000 infectious cases in total. The estimate above was based on some assumptions and limitations exited.

Background and current epidemic situation

In December, 2019, a series of pneumonia cases infected by a novel 2019-nCOV coronavirus emerged in Wuhan, Hubei Province, China. 2019-nCOV has demonstrated comparable transmissibility with infamous SARS and MERS, all belonging to the family Coronaviridae [1,2]. Surging with worrisome speed. As of 8am 30th January (Beijing Time) 2020, Approximate 8000 cases across the world have been confirmed, of which 2261 cases confirmed in Wuhan City and 2325 cases confirmed in other cities in Hubei Province [3]. There was a mean 3-7day incubation period. And the most common symptoms of illness were fever, cough, and myalgia or fatigue [4]. Articles on modelling epidemic trend of 2019-nCOV have been published [5,6]. The predicted epidemic peak will be in late February 2020. Effective interventions implemented by Chinese Government, the epidemic will gradually die off in late March 2020.

Transmission model

Due to Spring Festival, nearly 5 million people left off Wuhan before the traffic blockade January 10th-22th, 2020. Fortunately, most of travelers above moved around in Hubei Province [7]. As the intense intervention implemented, the outbreak in provinces other than Hubei has been effectively under control (Figure1).

The epidemic trend focused on Hubei Province was simulated by a SEIR model. We estimated a total of approximate 5000 cases of 2019-nCOV in Hubei Province (mainly distributed in Wuhan City) by 22th January 2020. The transmission rate β in Hubei was calculated as 0.8 from 12th December 2019 (the first 2019-nCOV case tracked) until 22th January 2020 (traffic blockade started). Under the intense intervention, we assumed the transmission rate β decreased to

0.005-0.1. With the assumption of no resurges resulted by virus mutation or unknown source of infection, the epidemic peak in Hubei will be within 28th January 2020 to 7th February 2020, up to 7000-9000 infectious cases in total.

Discussion

Compared with SARS in2003, the emergency response capabilities of Chinese government have been improved. Interventions or relevant policies, such as free treatment for 2019-nCOV infectious patients, wildlife trade ban during the plague, traffic control, have been implemented rapidly. All models are wrong, but some are useful! The estimate above was based on some assumptions and limitations exited. Affected by Spring Festival travel, the epidemic has spread rapidly and trend is difficult to simulate. And further investigations on potential spatiotemporal transmission pattern are warranted.

Model and Method

Part I

The total number of cases in Hubei Province by 22th January 2020 is given by [5]:

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

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

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

The daily probability of travel is calculated by:

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

The mean time to detection can be approximated by:

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

We set parameters and initial values as follows

Daily international passengers travelling out of Wuhan International Airport = 3301

Effective catchment population of Wuhan International Airport=19 million

Detection window (days) =10 days

The Exported number of confirmed cases by 22th January 2020 = 9

Ignoring sporadic cases in cities other than Wuhan, we estimated 5000 cases of 2019-nCOV in Hubei Province by 22th January 2020.

Part II

We proposed a SEIR model to simulate the transmission and trend of 2019-nCov in Hubei Province [6]. The population was divided into four compartments: susceptible individuals (S), asymptomatic individuals during the incubation period (E), confirmed infectious individuals (I), and recovered individuals (R). β denoted the mean person-to-person transmission rate per day in the absence of control interventions. Individuals in the incubation period progressed to the infectious compartment at a rate k. Infectious individuals recovered and died at the rate

γ.

$$
\begin{cases}
\dfrac{dS}{dt} = -\beta(t)\dfrac{SI}{N} \\[2mm]
\dfrac{dE}{dt} = \beta(t)\dfrac{SI}{N} - kE \\[2mm]
\dfrac{dI}{dt} = kE - rI \\[2mm]
\dfrac{dR}{dt} = rI
\end{cases}
$$

Simulation 1

We set parameters and initial values as follows:

Average incubation time (k) =7;

Average illness duration (r) =10;

Population (N) =19million;

Susceptible individuals (S) =19million minus 1;

Symptomatic individuals during the incubation period (E) =0;

Confirmed infectious individuals (I) =1;

Recovered individuals (R) =0;

By simulation, when β approximate 0.8, the total number of case would be up to 5000 by 22th January 2020.

Meanwhile, there were 10000 exposed people (E) and 1800 recovery people (R).

Simulation 2

We set parameters and initial values as follows

Average incubation time (k) =7

Average illness duration (r) =10

Population (N) =59.17million;

Transmission rate (β) =0.005 to 0.1 by 0.005

Susceptible individuals (S) =59.17 million minus (E+I+R)

Symptomatic individuals during the incubation period (E) =10000

Confirmed infectious individuals (I) =5000
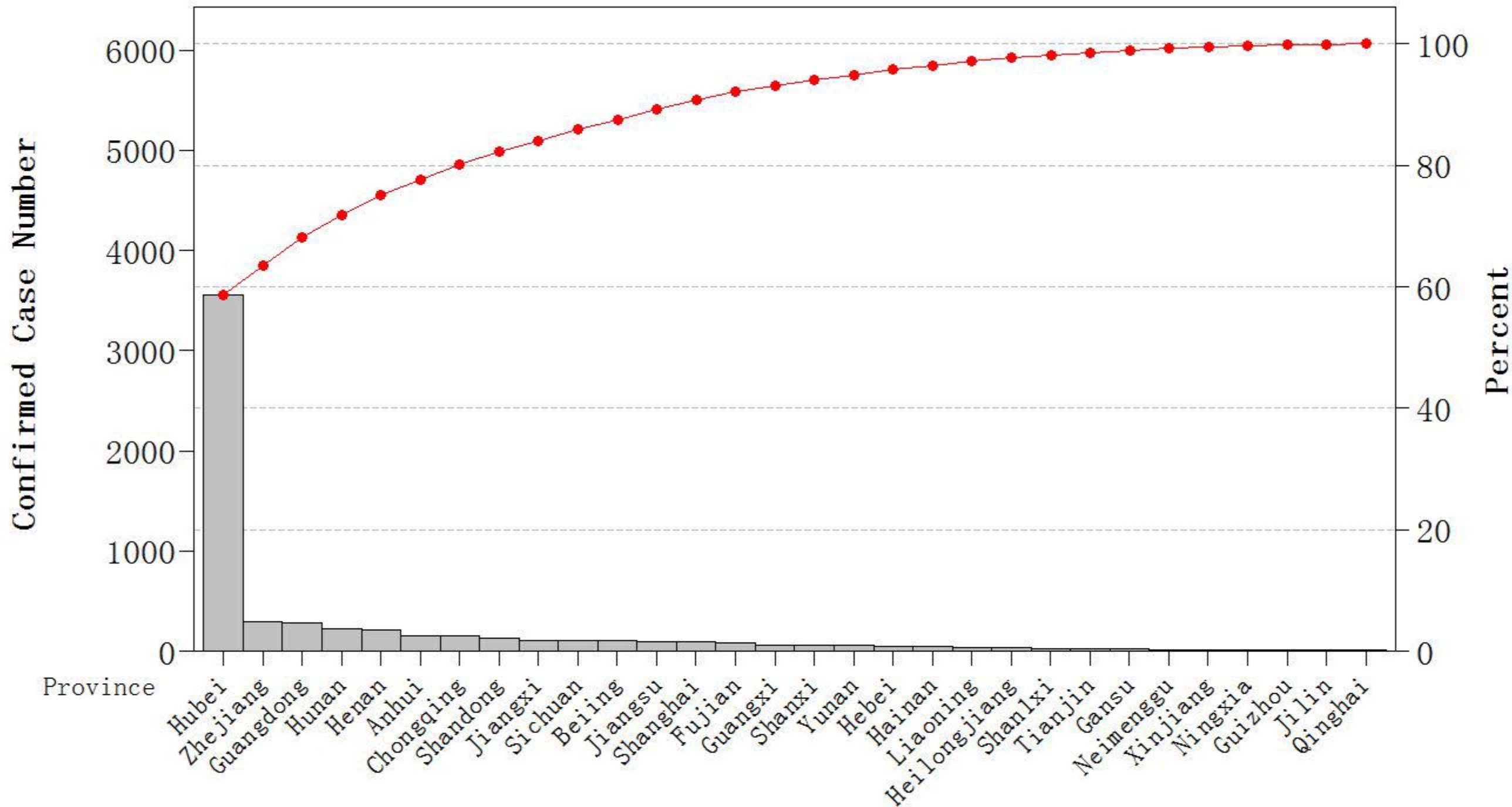
Recovered individuals (R) =1800

By simulation, the epidemic peak in Hubei will be within 28th January 2020 to 7th February 2020, up to 7000-9000 infectious cases in total (Figure 2).

References

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Province	Confirmed Case Number	Percent	Cumulative
Hubei	3554	59	59
Zhejiang	296	5	64
Guangdong	277	5	68
Hunan	221	4	72
Henan	206	3	75
Anhui	152	3	78
Chongqing	147	2	80
Shandong	130	2	82
Jiangxi	109	2	84
Sichuan	108	2	86
Beijing	102	2	87
Jiangsu	99	2	89
Shanghai	96	2	91
Fujian	84	1	92
Guangxi	58	1	93
Shanxi	56	1	94
Yunan	55	1	95
Hebei	48	1	96
Hainan	43	1	96
Liaoning	39	1	97
Heilongjiang	38	1	98
Shanlxi	27	0	98
Tianjin	27	0	99
Gansu	24	0	99
Neimenggu	16	0	99
Xinjiang	13	0	99
Ningxia	12	0	100
Guizhou	9	0	100
Jilin	9	0	100
Qinghai	6	0	100