COVID-19 Epidemic Prediction Model and Prevention and Control Analysis

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Abstract. COVID-19 infection was found in Wuhan area in early 2020. Because of the Data backlog in the initial period of Hubei province, it was not conducive to accurate establishment of the model. This article selected the number of diagnosed people in 40 districts and counties of Chongqing City near Hubei province for analysis and modeling. And the prediction model is divided into three stages. The first stage is the initial stage of prevention and control, and the virus transmission shows an exponential model growth. The second stage is the development period of prevention and control, the virus transmission shows a fluctuating state. In the third stage, which is in the mature stage of prevention and control, the virus spreads as a linear function. At the same time, the data curve of three stages and the reasons for its formation are analyzed. The laws revealed by this model have a certain theoretical basis for the prevention and control of new infectious diseases such as coronary pneumonia, which will have a certain guiding effect on the prevention and control of viruses in newly discovered countries and regions of the epidemic.

Keywords: COVID-19, Infectious, Mathematical Model, the Prevention and Control

1. Introduction

In early 2020, the novel coronavirus (COVID-19) came with such force that alarms went off in all provinces. In response to this outbreak, we took timely measures. As far as Chongqing is concerned, at the end of 2019, Chongqing residents working in Hubei province had returned home. Before the official announcement of Chongqing, there were 200,000 visitors from Wuhan to Chongqing, consecutive years [1]. This figure means that some passengers carrying the COVID-19 may have been to Chongqing before January 23 [2]. Chongqing is adjacent to Hubei province. It is not only connected by land, but also by water. In addition to the habit of similar and humanities dating, so the two places between people is particularly frequent.

From the above reasons, it can be seen that the epidemic situation in chongqing can reflect the real situation of the spread of an infectious disease from scratch. Therefore, this article selects 40 districts and counties in Chongqing, which are adjacent to hubei province, to predict the development of the epidemic situation, and the reasons are as follows.

First, when the epidemic began to spread, the diagnosis of disease process is too complicated, some
parts of the nucleic acid testing kit is facing the situation of insufficient, at the same time, the medical staff, treatment equipment and beds in infectious disease hospitals in each region are limited, and the number of cases that can be diagnosed daily is limited. Therefore, if only the number of diagnosed people in Hubei province is observed, the data may reflect the detection capacity of medical institutions under certain conditions, rather than the actual spread of the disease. Therefore, there is a "temporary backlog" of data in Hubei province's newly started data, which is a problem in the diagnosis ability of medical institutions during an emergency.

Second, if the number of people diagnosed in Hubei province, Hong Kong, Macao and Taiwan is removed, and the data of the remaining 30 provinces in the country are selected, it is predicted that the data will be closer to the actual epidemic development than Hubei's data. However, China has a large area, large temperature differences between north and south, and uneven population density distribution, and the actual prevention and control of the epidemic situation may vary across the country, and the prediction will also be biased. These data still unable to accurately establish the prediction model.

Third, Chongqing is close to Hubei province, with a population of more than 31 million and a similar population density. In the early stage of the epidemic, 6 people were confirmed on January 21, 3 on January 22, 18 on October 23 and 30 on 24th, indicating a few days before the 21st, there may be about 1 or 2 people in a certain day, which is basically in line with the emergence of the first person of the infectious disease in the region. It can accurately predict the spread of the epidemic. Using this data to predict, it is also more in line with the actual development of the epidemic [3].

2. Epidemic Assessment

2.1 Data Collection

Since the outbreak occurred, the daily confirmed epidemic data publicly released by the National Health Commission and Hubei Province and Chongqing Municipal Health Commission are shown in Table 1. It can be seen from Table 1 that on January 21, 105 people were diagnosed in Hubei Province, 149 people nationwide, and 44 people except Hubei. The initial data of the model cannot be accurately seen. The smaller the initial data, the more predictable the model is. The situation is more real. That is how many people were infected on a specific day, so the initial value of the model is not clear, and the prediction will be biased. Therefore, using data from Chongqing to build a model is better than using data from Hubei and the whole country to predict the true situation of the number of people diagnosed in a certain city in the future [4]. This article statistically and modeled the number and growth rate of daily confirmed growth after January 21, and selected the data of 40 districts and counties in Chongqing. At the same time, the initial data is the sum of imported cases in Chongqing, which is relatively timely and is the data of human-to-human transmission, in which the growth rate = the increased number/the number of confirmed cases [5].

**Table 1.** Daily confirmed cases in Hubei, Chongqing and the whole country and the growth rate

| date       | The national | hubei | 30 provinces | The cumulative | The model number | Daily number of confirmed cases | The growth rate |
|------------|--------------|-------|---------------|----------------|------------------|-------------------------------|-----------------|
| Jan 21st   | 149          | 44    | 44            | 6              | 1                | 6                             | 1               |
| Jan 22nd   | 571          | 69    | 502           | 3              | 2                | 9                             | 0.33333         |
| Jan 23rd   | 259          | 105   | 154           | 18             | 3                | 27                            | 0.666667        |
| Jan 24th   | 444          | 180   | 264           | 30             | 4                | 57                            | 0.526316        |
| Jan 25th   | 688          | 323   | 365           | 18             | 5                | 75                            | 0.24            |
| Jan 26th   | 769          | 371   | 398           | 35             | 6                | 110                           | 0.318182        |
| Jan 27th   | 1771         | 1291  | 480           | 22             | 7                | 132                           | 0.166667        |
| Jan 28th   | 1459         | 840   | 619           | 15             | 8                | 147                           | 0.102041        |
| Date      | Jan 29th | Jan 30th | Jan 31st | Feb 1st | Feb 2nd | Feb 3rd | Feb 4th | Feb 5th | Feb 6th | Feb 7th | Feb 8th | Feb 9th | Feb 10th | Feb 11th | Feb 12th | Feb 13th | Feb 14th | Feb 15th | Feb 16th | Feb 17th | Feb 18th | Feb 19th | Feb 20th | Feb 21st | Feb 22nd | Feb 23rd | Feb 24th | Feb 25th | Feb 26th | Feb 27th | Feb 28th | Feb 29th |
|-----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|           | 1737     | 1982     | 2102     | 2590    | 2829    | 3235    | 3887    | 3694    | 3143    | 3399    | 2656    | 3062    | 2478    | 2015     | 15152    | 5090     | 2641     | 2009     | 2048     | 1886     | 1749     | 394      | 889      | 397      | 648      | 409      | 508      | 406      | 433      | 327      | 427      | 573      |
|           | 1032     | 1220     | 1347     | 1921    | 2103    | 2345    | 3156    | 2987    | 2447    | 2841    | 2147    | 444     | 2097    | 1638     | 14840    | 4823     | 2420     | 1843     | 1933     | 1807     | 1693     | 349      | 631      | 366      | 630      | 398      | 499      | 401      | 409      | 318      | 423      | 570      |
|           | 705      | 762      | 755      | 669     | 726     | 890     | 731     | 707     | 696     | 558     | 509     | 444     | 381     | 377      | 312      | 267      | 326      | 158      | 115      | 79       | 56       | 45       | 258      | 31       | 18       | 11       | 9        | 5        | 4        | 3        | 3        |
|           | 18       | 41       | 32       | 24      | 38      | 37      | 29      | 23      | 22      | 15      | 20      | 22      | 18      | 19       | 13       | 11       | 8        | 7        | 2        | 5        | 7        | 5        | 3        | 1        | 2        | 1        | 0        | 0        | 0        |
|           | 9        | 10       | 11       | 12      | 13      | 14      | 15      | 16      | 17      | 18      | 19      | 20      | 21      | 22       | 23       | 24       | 25       | 26       | 27       | 28       | 29       | 30       | 31       | 32       | 33       | 34       | 35       | 36       | 37       | 38       |
|           | 165      | 206      | 238      | 262     | 300     | 337     | 366     | 389     | 411     | 426     | 446     | 468     | 486     | 505      | 518      | 529      | 537      | 544      | 551      | 553      | 555      | 560      | 567      | 572      | 573      | 576      | 576      | 576      | 576      | 0        |
|           |          |          |          |         |         |         |         |         |         |         |         |         |         |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          | 0.109091 |

2.2 Establishment of Model

Established Table 1, the growth rate of newly diagnosed people in Figure 1. This analysis divides the number of diagnosed people into three stages. The first stage is January 19-24. The day is the early stage of prevention and control, and the second stage from January 19 to 24 is the development period of prevention and control, and the third stage from February 1 to 29 is the mature period of prevention and control [6].
It has been several investigations in January that have been made.

In the early stage of the spread of the new coronavirus, because people do not have a deep understanding of the virus, and the daily flow is not restricted, the growth mode is an exponential function. \( y \) represents the number of infections, \( r \) is the growth rate:

\[
y = r \cdot y(t)
\]

Solve the above differential equation, \( y(t) = y(0) \), where \( y(0) \) is the number of confirmed patients on January 19, that is, the initial number of confirmed patients. In the early stage of the epidemic, the above index model can be used for assessment. The data model in this article is analyzed using the number of 6 diagnosed people announced by the Chongqing Municipal Health Commission on January 21. In fact, there were already patients before, but there was no timely detection and other reasons, which caused 6 people to be reported on January 21st,[4] so the number of people who had been infected before January 21st was predicted, assuming 1 person on January 19th, 2 people on January 20, 3 people on January 21, a total of 6 people, using Chongqing Health and Health Commission data to analyze with an exponential model, the chart of the number of diagnoses in the first stage is shown in Figure 2, using the index to fit the formula.

\[
Y = y(0) \cdot e^{0.6742x}
\]

The model fitting degree R² is highly fitted, which is about 91%, in which \( y(0) \) is the initial number of people, that is, the number of people in no. 19 is 1. If evaluated according to the results of this model, the number of infections can reach 847 in 10 days, the number of infections in 24 days can reach 24587.

The second stage is to prevent and control the fluctuation model in the development period from January 26 to 31. But in fact, the Chongqing Municipal Government took timely and strong measures. On January 24, the first-level response to major public health emergencies was initiated, and the investigation of 80% of the city’s permanent population was completed within three days. These several decision-making arrangements have taken time for the Chongqing epidemic to defend the war. It is also these powerful measures that have played a very important role in the next 7 days. As can be seen from Figure 3, from 1. During the 7-day period from the 25th of January to 31st of January, the
data did not continue to increase according to the previous index model, but showed a volatile state. It can be seen that the government’s prevention and control played a role status.

**Figure 3. Number of confirmed patients in the second stage**

The third stage is the linear state of the prevention and control maturity from February 1 to 24. The newly diagnosed cases every day are shown in Figure 4 below. The number of diagnosed patients in this period presents a linear function: \( y = kx + b \). This stage is the mature stage of prevention and control [7,8].

**Figure 4. Number of patients diagnosed in the third stage**

It can be seen from the figure that chongqing has taken actions to prevent and control the epidemic situation in various districts and counties one after another. In this stage, the prevention and control of each district and county has been mature, and the number of newly added people in the figure is gradually decreasing [9]. We made a linear trend analysis, and the results are as follows:

\[
y = -1.4513x + 32.225 \quad (3) \\
R^2 = 0.8523 \quad (4)
\]

The linear fitting degree of R2 is about 85%, which is a high degree of fitting. This shows that the epidemic has been effectively controlled by the efforts of the Chongqing people. After February 1, the daily growth rate is highly fitted with the \( y = kx + b \) function as the model, and it decreases rapidly with time. The strength of Chongqing’s prevention and control of viruses can be expressed by the slope k value. The greater the prevention and control strength, the greater the absolute value of the slope k, the faster the function line will reach 0, that is, the number of diagnoses will reach the peak faster. When the newly diagnosed number is 0, that is, \( y = 0 \), then \( x \) is approximately equal to 23. From February 1, the increase in the number of diagnosed days in 40 districts and counties in Chongqing will be confirmed and cleared around February 24. In the next time around February 24, there will be no increase in the number of diagnoses. It can be said that the Chongqing municipal government and people are very efficient in preventing and controlling the epidemic, and have achieved very good results [10-11].

3. Epidemic Development Analysis

In the first stage, COVID-19 appeared before the Spring Festival. At this time, many migrant workers in Chongqing concentrated on returning to their hometowns. The movement of people had a great
impact on the spread of the epidemic. So at this time, the Chongqing Municipal Government intensively issued relevant policies to prevent and control the epidemic.

In the second phase, after experiencing the sharp increase in the previous 4 days, the government launched a disinfection measure on January 22 on all trains, buses and key places with heavy traffic in Chongqing, and comprehensively tested passengers coming to Chongqing. So between January 25 and January 31, the number of newly diagnosed patients fluctuated, but did not continue to increase according to the previous index model. It can be seen that the government's various levels of prevention and control policies have played a role. These 7 days are the game state of prevention and control and virus, and the key to prevention and control. During the period, we cannot be discouraged. As long as we continue to do strict anti-epidemic work, our city's epidemic situation has been effectively controlled, laying a solid foundation for economic and social resumption of production.

In the third stage, specific measures such as prevention and control, prevention and control, isolation, detection, shut-down, admonishment, disinfection, closure (management), service, and treatment are in place in the previous two stages. There is no large-scale and widespread infection in Chongqing. In the battle between prevention and control and virus, prevention and control defeated the spread of the virus. The function model fitting in this article is expected to be after February 1st, and the number of newly diagnosed people will be close to 0 in about 23 days. The actual situation is that Chongqing will increase on February 25th. The number of diagnoses is 0, and the model fits the actual situation very well. This shows that some experts have a gap between the estimated model and the actual situation without examining the accuracy of the basic data. In addition, it also shows that the Chongqing Municipal Government and the people have worked together to achieve a great victory in the fight against epidemic disease.

4. Conclusion

The model studied in this paper has a certain theoretical basis for the prevention and control of infectious diseases. After the outbreak, under the correct epidemic prevention strategy, the development rules of infectious diseases such as new coronary pneumonia are revealed. Regional and national virus prevention and control have a certain guiding role. As of March 23, Chongqing has had no newly diagnosed cases for 28 consecutive days, and resumption of production and production has begun in an all-round way. The epidemic prevention work has changed from internal prevention to external input. The laws summarized in the article are scientifically measured and accurate. Epidemic prevention plays a good reference role.

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