Simulation of epidemic trends for a new coronavirus under effective control measures

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Abstract

Objective: To simulate carriers of a new type of coronavirus (2019-nCoV) entering uninfected areas, and, on the premise of the effective treatment and isolation of diseased patients and reducing close contact between people in the area, simulate the epidemic of 2019-nCoV infection trend.

Methods:

Public information was used to obtain:

- the disease latency of 2019-nCoV-infected patients,
- the time to cure the disease after consultation,
- and the probability of close contact with the infection.

A simple interactive environment was built using agent-based modeling.

It was assumed that the first 2019-nCoV infected person in a specific susceptible population could be effectively treated and isolated after clinical symptoms appear, while close contact between the rest of the population could be minimized.

Consequently, it was possible to estimate the prevalence of 2019-nCoV infection after virus carriers enter an uninfected population.

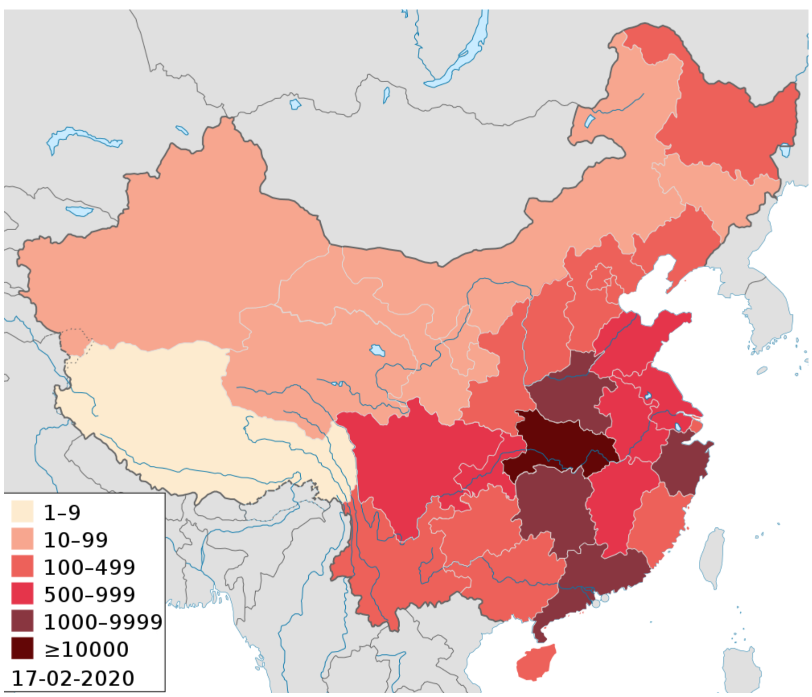
Results: As of January 30, 2020, the latency of the disease in patients infected with 2019-nCoV has been 6.6 days (95% CI: 5.9-7.5), and the time to cure after the onset of infection with 2019-nCoV has been 9.8 days (95% CI: 8.8 -10.8).

When a virus carrier enters an uninfected 2019-nCoV population, the number of infected people increases as the number of daily close contacts in this population rises.

After the first infection occurs in a group, the number of infections caused by close contact with 15 people daily is 42.4 times that of close contact with 5 people.

After the incubation period ends, the number of 2019-nCoV infections remains stable for a period. The number of infections starts to decline after 16 days, and the number of patients will reach 0 after 27 days.

Conclusion: In an area newly infected with 2019-nCoV, with effective treatment and isolation of patients at the onset of 2019-nCoV infection, and assuming effective reduction of close contact between the population in the area after a case is found, it seems the transmission of 2019-nCoV may not continue more than 1 month.



In December 2019, there was a case of viral pneumonia in Wuhan. After confirming that the pathogen of this disease is a new coronavirus, the World Health Organization (WHO) confirmed and named it 2019-nCoV. The pneumonia caused by this pathogen infection is called a novel corona virus pneumonia.

The WHO report shows that person-to-person transmission is occurring [1]. At present, the number of confirmed cases of the virus infection is still increasing rapidly. In 2019, 31 provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps have reported confirmed cases of 2019-nCoV, with a total of 17,205 confirmed cases and 21 558 suspected cases (as of 24:00 on February 2) [2].

In addition, more than 20 countries including Thailand, Japan, South Korea, and the United States have also confirmed new cases of coronavirus pneumonia. On January 31, 2020, the WHO further identified 2019-nCoV-infected pneumonia as a public health emergency of international concern [3].

In order to cope with this sudden public health problem, Wuhan officially implemented the "Class A infectious disease blockade" as stipulated by the "Infectious Diseases Prevention and Control Law" on January 23.

All provinces have officially launched a major public health emergencies response: Residents encouraged to take personal protective measures such as wearing masks in public places and reducing travel; patient isolation and treatment, seeking to control the source of infection and cut off transmission routes to effectively control the epidemic.

At this stage, it is important to better understand the mode of transmission of 2019-nCoV among the population and the effects of control measures. This information will help when: deploying and coordinating further epidemic prevention and control, evaluating the effectiveness of control measures, and in helping reduce panic.

To study the prevalence of infection in a population, this study used agent-based modeling (ABM) to simulate an interactive environment over a certain space-time range. Asymptomatic 2019-nCoV carriers entered the uninfected population within a certain space-time range.

This study assumes that after the onset of 2019-nCoV infection in this space-time range, patients can be effectively treated and isolated, and that close contact between people can be effectively reduced.

Furthermore, this study simulates the trend of 2019-nCoV infection at different levels of close contact in order to provide relevant information and references.

1 Materials and methods

1.1 Research Materials

In this study, the following data were used to simulate the epidemic trend of 2019-nCoV:

- the 2019-nCoV close-infection probability,
- the disease incubation time of patients infected with 2019-nCoV,
- the time to cure the disease after consultation,
- and the number of close contacts per person per day.

The data are obtained from public information [4, 5].

The incubation time is the difference between the first exposure to 2019-nCoV and the time of onset, and the disease cure time is the difference between the 2019-nCoV diagnosis time and the cure discharge time.

As of January 30, 2020, 64 cases of patients with detailed incubation period and 84 cases of patients with detailed cure information were collected through public information channels such as online media.

Due to the lack of data on the probability of contact infection in 2019-nCoV, the present study estimates the number of confirmed cases of 2019-nCoV infection in the country and the number of people in close contact with 2019-nCoV infection in the country.

It was assumed that non-onset individuals (including susceptible residents and patients still in the incubation period) make daily close contact with 5, 10, and 15 people, respectively, to assess the impact of different levels of close contact on the 2019-nCoV epidemic.

1.2 Research methods

In this study, the Bootstrap method was used to sample 1,000 times:

- the disease latency of patients infected with 2019-nCoV,
- the infection probability when exposed to 2019-nCoV,
- and the uncertainty of the time to cure the disease after its onset

Agent-based modeling (ABM) was used to analyze the 2019-nCoV trend.

ABM is a computational model used to simulate the actions and interactions of agents with autonomous consciousness. It has been widely used in many fields including biology, ecology and social sciences [6].

This study uses an ABM model to simulate the outbreak trend of 2019-nCoV.

Since the 2019-nCoV propagation process is relatively complicated, it is difficult to obtain relevant parameters for constructing the ABM model, so the complex process in the actual state of 2019-nCoV propagation is simplified to some extent.

The person object is the basis of this ABM model and the study assumes that the status of each person in the ABM model can be divided into four states: susceptible, infected, sick, and immune.

A susceptible subject is infected after being infected with a disease. This state has a certain incubation period, and during this period, it can be transmitted with a certain probability to other subjects with whom there is contact.

After the incubation period, the infectious disease becomes apparent and a person is considered sick. In this study, it is assumed that:

- all sick people can be effectively treated and isolated
- as soon as the first case of the disease is found, all the people can effectively reduce close contact
- after a certain period of treatment, a person is free of the disease and immune

Due to the lack of information about the specific duration of immunity after a 2019-nCoV infection has cured, this study did not assess the impact of a person's immunization on disease transmission.

For this study, a simple interactive environment was constructed using an ABM model. It assumed that the range of activities for each person took place at home or in public places.

Before the symptoms of the disease appear (that is, the subject is not infected or the subject is in the incubation period), the subject normally leaves home to go to a public place, and then returns home.

In order to simulate the epidemic trend of 2019-nCoV, a total of 10,000 subjects were set up, and one of them was randomly infected.

The ABM simulation experiments were performed 10 times in total, and the average value was taken as the experimental result.

The data was sorted and cleaned up using R3.6.2 software, and the ABM model was implemented using AnyLogic software.

2 Results

2.1 Model parameters

The model parameter setting results are shown in Table 1.

Parameter	Value
Close contact infection rate of 2019-nCoV infected patients（%）	10.4（8.7，13.0）
The incubation time of patients infected with 2019-nCoV（days）	6.6（5.9，7.5）
The cure time, after the treatment for 2019-nCoV infection (days)	9.8（8.8，10.8）

Note: 2019-nCoV close contact infection rate = number of confirmed cases nationwide / number of close contacts cases nationwide.

2.2 Novel coronavirus trends under effective control measures

When the first 2019-nCoV carrier entered a susceptible population, and as the number of close contacts between people increased, the number of 2019-nCoV infections increased.

From the onset of the first 2019-nCoV infection, the number of people infected with the virus in close contact with 15 people was 42.4 times that of those in close contact with 5 people.

After the onset of the 2019-nCoV infection, the number of 2019-nCoV infections remained stable for a certain period of time, due to the effective isolation of patients and reduction of close contact between other members of the population. Then, within 16 days there was a decline, and the number of patients on day 27 approached zero, as shown in Figure 1.

[graph]

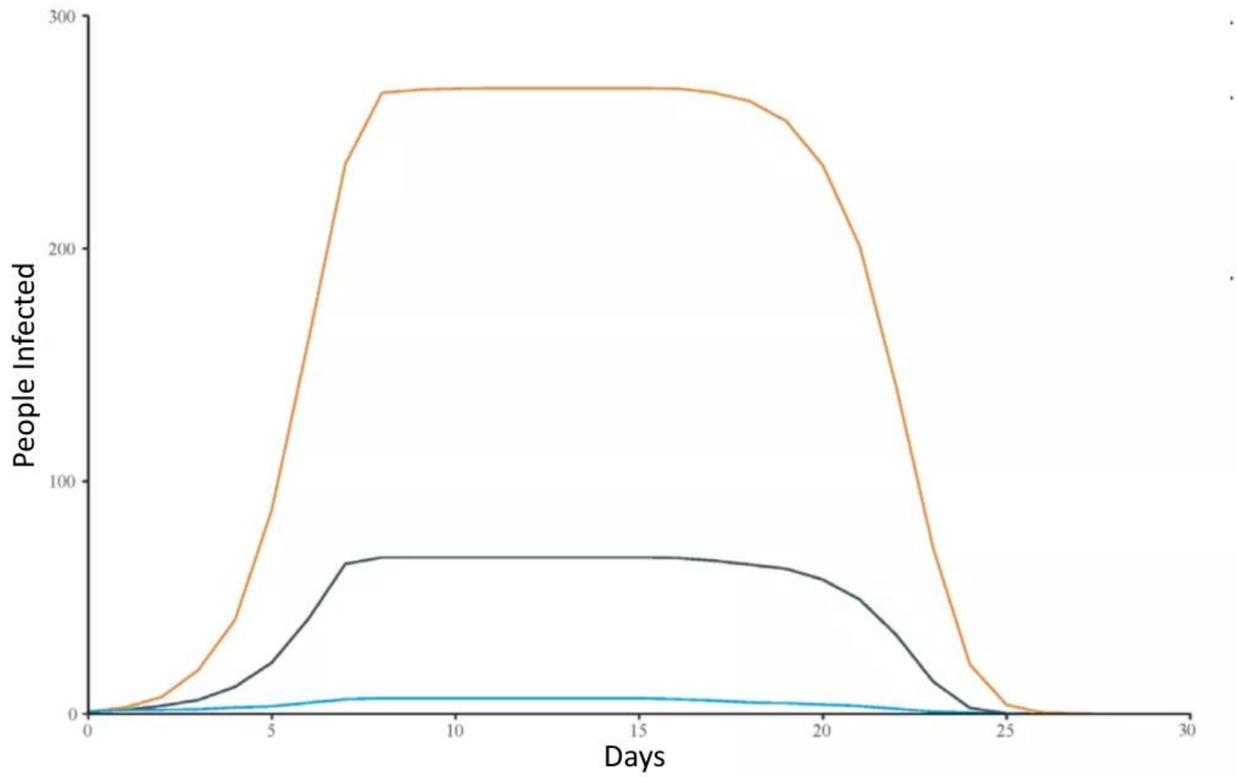


Figure 1. Novel coronavirus trends under effective control measures.

3 Discussion

This study simulated, in a simple interactive environment, 2019-nCoV infections over time after a carrier entered a susceptible population.

The results show that as the number of people in close contact increased, the number of people infected with 2019-nCoV increased.

In an ideal situation, the number of patients infected with 2019-nCoV dropped to 0 after the 25th day. For this to happen, after the first person infected with 2019-nCoV appears in the susceptible population, all members of this group should effectively reduce close contact, and all patients infected with 2019-nCoV must be effectively isolated and treated.

This study estimates the latency of infection with 2019-nCoV. The results of this study show that the disease latency of patients infected with 2019-nCoV is 6.6 days (95% CI: 5.9-7.5), which is slightly higher than the previous published results [7].

Research by Qun Li et al. analyzed 10 confirmed 2019-nCoV infection cases and determined that the latency of 2019-nCoV infection was 5.2 days (95% CI: 4.1-7.0) [7]. This difference may be due to the relatively early report time and relatively small number of cases reported by Qun Li et al.

Reducing the close contact between people is an important means of control for the spread of 2019-nCoV, and it is also the focus of prevention and control after the outbreak.

The results of this study indicate what happens when 2019-nCoV carriers enter a susceptible population that has not been infected with 2019-nCoV.

During the incubation period, as the number of close contacts between people increases, the number of people infected with 2019-nCoV increases, and, when the number of contacts with people is 15, the number of people infected with the virus is 42.4 times that of when the number of contacts with people is five.

Therefore, reducing the close contact between people will help to control the close contact between latent (asymptomatic) virus carriers and healthy susceptible individuals, thereby reducing the number of virus infections in susceptible people.

At the same time, it is of great importance to adopt preventive public health measures such as stricter medical observations of close contacts.

It should be noted that with the end of the Lunar New Year, the upcoming "back to work tide" may bring tremendous pressure on the prevention and control of 2019-nCoV, especially for labor importing provinces.

To prevent a second outbreak, actively implementing early detection, early isolation, early reporting, and early treatment are important means to control the 2019-nCoV epidemic.

At the same time, promoting correct lifestyle habits, including wearing masks correctly, washing hands properly and in a timely manner, reducing the number of people in closed places, reasonable diet, moderate exercise, smoking cessation and alcohol restriction, and psychological balance will help control the 2019-nCoV epidemic.

In this study, a method based on agent-based modeling was used to analyze the spread trend of the epidemic under controlled conditions.

The main parameters for the modeling were obtained from public information. However, considering the incubation period and treatment time, there may still be a certain number of patients in the incubation period not yet sick, and many patients are still receiving treatment.

Furthermore, the data collected through public information is relatively limited, so there may be some errors in the evaluation of the incubation period and treatment time, and such errors will have a certain impact on the model.

Overall, the assumptions of this study may lead to a certain underestimation of the duration of 2019-nCoV.

Nevertheless, in this study, by simulating the process of virus transmission to susceptible populations by latent virus carriers under ideal public health conditions, we found that in the case of effective treatment and isolation of patients infected with 2019-nCoV (under the premise of effectively reducing close contact between people after an infected case was found), the spread of 2019-nCoV in a certain space may not exceed 1 month. The results may provide some reference for the public and related staff.

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