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A Study on the Transmission and Control of COVID-19 Epidemic Disease of New Coronavirus Pneumonia

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Abstract: Since the outbreak of new coronavirus pneumonia in December 2019, all countries in the world have taken preventive and control measures. By the end of April, the epidemic situation in China had been controlled, but the situation abroad was still grim. Based on the current global coronavirus-induced pneumonia epidemic situation, this paper studies the model of infectious diseases and predicts their development trend, and gives reasonable prevention and control suggestions according to their characteristics. According to the prediction of the future development of the virus, we refer to the relevant data of the new coronavirus pneumonia epidemic situation, and establish a dynamic model based on the differential equation of the SIER chamber model from the point of view of the transmission infectious diseases. The number of patients diagnosed with latent period disease increased exponentially according to the relevant data, assuming λ and other parameters, and calculating the approximate function of infection rate and cure rate. The differential formula of SIER model is used to deduce the change function of the proportion of all kinds of population with time. By integrating the collected data, we use SPSS fitting to obtain the function expression of infection rate and cure rate, and substitute the improved model equation to solve the problem. Our model is characterized by real-time, intuitive and reliability. In the whole process of analysis and solution, the actual development situation is simulated by numerical fitting of the latest epidemic situation data, and the data processing by drawing line and table is clear and intuitive, which improves the accuracy and testability of the conclusion. Each parameter in the model takes into account the characteristics of 2019-nCoV transmission and the possible phenomena and effects of epidemic situation, so our model is reliable.

1. Introduction

Since the 21st century, infectious diseases have been the world's biggest health problems. Since December 2019, a new type of coronavirus pneumonia has appeared in Wuhan, Hubei Province. With the continuous development of the epidemic situation, other provinces and cities in China and many overseas countries have also appeared the phenomenon of infection. After the outbreak of new coronavirus pneumonia (COVID-19), China has quickly taken strong prevention and control measures to prevent the spread of the epidemic. By the end of April 2020, the situation of prevention and control of the global epidemic of new coronavirus pneumonia (COVID-19) is still very serious.

The prevention and control measures and prevention and control measures in different countries are different, and the epidemic stage is also different. For example, a large-scale rally in South Korea in late February caused a surge in infection, with the enhancement of epidemic prevention consciousness and reasonable and timely prevention and control measures, the epidemic situation has been effectively controlled. In contrast, countries such as the United Kingdom and the United States, without timely and reasonable vaccination measures, the number of infections is still growing significantly, the development is extremely poor. The future direction and eventual scale of the global epidemic remain unknown. However, after studying the relevant data and data of the epidemic situation of the new coronavirus pneumonia (COVID-19), we can quantitatively study the transmission route, transmission speed, spatial range and kinetic mechanism of the new coronavirus pneumonia, and summarize the transmission characteristics of the new coronavirus. According to the analysis of the existing data and data, the numerical simulation is carried out, and the mathematical model is established to predict the future trend of the virus scientifically and reasonably. At the same time, please give suggestions for prevention and control, actively solve the major problem of epidemic prevention and control, and study the relationship between different prevention and control measures and the intensity of prevention and control and virus transmission.

2. Modeling and Solving

2.1 A mathematical model to predict the future of the virus

2.1.1 Model building

According to the SEIR model, we will establish the differential equation solution, which will consider the susceptible, the sick, the exposed and the rehabilitated. Infection of infected susceptible people, susceptible people infected with the virus into the incubation period, latent people have a certain probability of recovery, there is also a certain probability of diagnosis, infected people will be cured by treatment, and think that after recovery can no longer infect the disease.

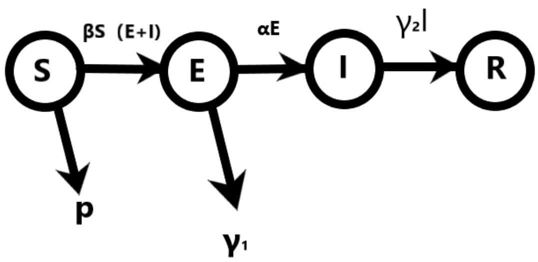

Figure 1: SEIR model diagram

The differential equations are:

$$\frac{dS}{dt} = -\beta IS, \quad \frac{dE}{dt} = \beta IS - (\alpha + \gamma_1)E$$

$$\frac{dI}{dt} = \alpha E - \gamma_2 \mathrm{I}, \quad \frac{dR}{dt} = \gamma_1 E + \gamma_2 I$$

Crest pneumonia transmission routes are mainly direct transmission, aerosol transmission and contact transmission [1]. Because people did not take a series of measures in the early days to wear masks and reduce the gathering of public places, and the National Health and Health Commission expert group did not publish conclusive "human" information, patients can freely contact and infect susceptible people. Because of the rapid spread of the virus, the spread rate is relatively rapid, the epidemic situation is relatively rapid, under this condition, the patients per day contact r susceptible people, the number of new suspected patients:

$$\Delta E = I(t) * r * \Delta t.$$

The r value is confirmed according to the number of new and cumulative close contacts and new confirmed cases per day issued by the State Health and Health Commission of the people's Republic of China from January 22 to March 15 in the notice of the new coronavirus pneumonia (http://www.nhc.gov.cn/). r=5 is assumed.

Suspected patients are divided into virus carriers and non-virus carriers, in which virus carriers will enter the incubation period because of virus infection, while non-virus carriers will eventually return to normal and return to healthy people. A proportion of suspected patients with virus carriers λ,so the number of new incubation periods is$\Delta Q = \Delta E \cdot \lambda$.During the incubation period, the number of people who become diagnosed daily$\Delta I = \beta_1 \cdot Q(t) \cdot \Delta t$, Assuming the incubation period$a_1$toa_2, At a stable stage, as the number of days increases, the number of people who are infected with the virus becomes more and more confirmed, with each carrier having the virus every day$(1-(1-1/(a_2-a_1)) \cdot e^{-1})$ The probability becomes the confirmed infected person, the new patient number$\Delta I = (1-(1-1/(a_2-a_1)) \cdot e^{-1}) \cdot \Delta Q \cdot \Delta t$. With the increase of the number of days, the number of cure and death will increasing, and the probability distribution will increase exponentially, assuming that the number of days of cure isa_3, number of people exiting the system of transmission

$$\Delta T = (1-1/a_3) \cdot e^{-1} \cdot I(t) \cdot \Delta t.$$

According to the above formula:

$$Q = \lambda \cdot E$$

$$Q(t+\Delta t) - Q(t) = \lambda \cdot r \cdot I(t) \cdot \Delta t - (1-(1-1/(a_2-a_1)) \cdot e^{(-t)}) \cdot Q(t) \cdot \Delta t$$

$$I(t+\Delta t) - I(t) = (1-(1-1/(a_2-a_1)) \cdot e^{(-t)}) \cdot \Delta Q \cdot \Delta t - (1-(1-(1/a_3)) \cdot e^{(-t)}) \cdot I(t) \cdot \Delta t$$

$$T(t+\Delta t) - T(t) = (1-(1-(1/a_3)) \cdot e^{(-t)}) \cdot I(t) \cdot \Delta t$$

So launch:

$$\frac{dQ}{dt} = \lambda \cdot r \cdot I(t) - (1-(1-1/(a_2-a_1)) \cdot e^{(-t)}) \cdot Q(t)$$

$$\frac{dI}{dt} = (1-(1-1/(a_2-a_1)) \cdot e^{(-t)}) \cdot Q(t) - (1-(1-(1/a_3)) \cdot e^{(-t)}) \cdot I(t)$$

$$\frac{dT}{dt} = (1-(1-(1/a_3)) \cdot e^{(-t)}) \cdot I(t)$$

2.1.2 Model solving

To solve the differential equation and make the corresponding curve, the corresponding parameters are set up first. Because of the exponential growth of the number of people diagnosed in the latent period, the infection rate is also exponential distribution. We first make the hypothesis that we can assume that the proportion of virus carriers in the number of suspected patients is 0.25, and then to the existing research hypothesis a1=3, a2a1=14, a3a1=24. MATLAB software is used to solve the corresponding model and make the image.

Before the intervention, the epidemic situation was predicted, and the isolation intensity p was added to predict the epidemic situation after a series of measures were taken. Then improve the model, we collate the collected data according to the Excel, calculate the cure rate and infection rate per unit time, through the regression fitting of spss software, get the fitting equation of cure rate and infection rate, and substitute the SEIR model to solve the problem. The specific equations are as follows:

$$\frac{dS}{dt} = -\beta IS, \quad \frac{dE}{dt} = \beta IS - (\alpha + \gamma_1)E$$

$$\frac{dI}{dt} = \alpha E - \gamma_2 \mathrm{I}, \; \frac{dR}{dt} = \gamma_1 E + \gamma_2 I$$

2.1.3 Model results

In the early years, the new coronavirus pneumonia spread only in severe areas, which did not attract the widespread attention of people and the government. The government and local authorities did not take strict control measures, the social order was normal, and the normal contact between people was normal. People's epidemic prevention thought is weak, isolation degree is poor. The results are shown below.

At the later stage, the government strengthened the control, when we introduced the isolation intensity p, we can find that under the control, the proportion of infected persons increased slowly, the proportion of exposed persons showed a significant inflection point, and then all kinds of proportions reached stability.

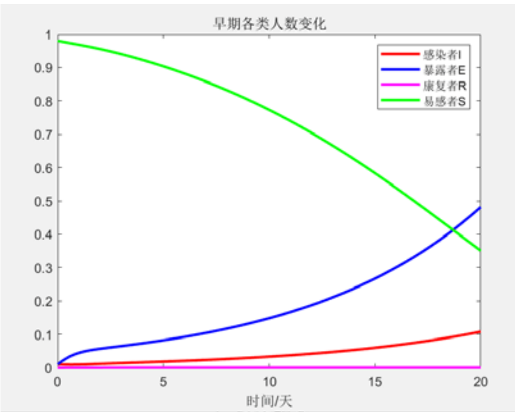

Figure 2: Early population change charts

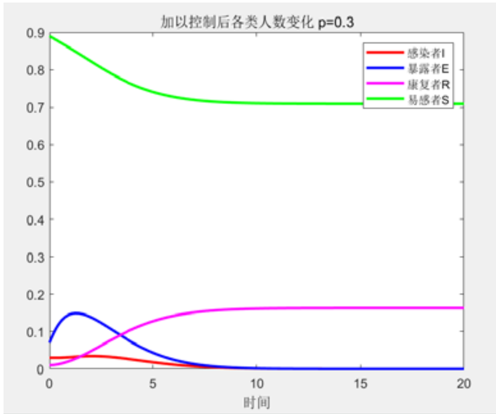

Figure 3: Population changes by category P=0.3

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