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Research of COVID-19 epidemic Model based on SEIR Model

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Abstract: This article mainly studies the infectious disease model of COVID-19. Based on the SEIR model, the epidemic prevention and control are divided into two stages according to my country's national conditions. The subjects of the study are normal people, lurking people, confirmed people, cured people, and dead people. Establish differential equation models and solve parameters for analysis and prediction. At the same time, the basic infection number is defined to compare the size of the basic infection number in the two cases of China's unmanned intervention and related prevention and control measures, and draw the conclusion that China's epidemic prevention and control policy is obviously effective.

1. Introduction

COVID-19 (Corona Virus Disease 2019) is an infectious disease that began to break out at the end of 19 years and is spreading widely around the world [1]. The outbreak and spread of COVID-19 have a great impact on people's lives and economic development all over the world. On this basis, we also think about the spread of the epidemic in other countries where the epidemic is developing seriously [2]. Therefore, this paper collects the number of confirmed, dead and cured people of COVID-19 in China at each time point, establishes an appropriate mathematical model, predicts the development [3] of the next epidemic situation according to the established infectious disease model, and comments on the relevant measures made by the government and health departments [4].

2. Model assumptions

(a) Suppose the development of the epidemic is divided into two stages:

(b) Latent patients are quarantined, confirmed patients are hospitalized, and the deceased does not have access to others. (c) Infectious people (undetected latent patients and unisolated latent patients) can infect normal persons. (d) Normal people have a certain probability of turning into latent patients after infection. (e) Unisolated latent patients will not get sick while waiting for isolation, and will eventually be quarantined. (f) All latent patients will develop the disease during the incubation period and will certainly be diagnosed as a confirmed patient after the onset of the disease.

Table 1: Two-stage comparison diagram

Stage1	Stage2
The number of diagnosed patients is small, and latent patients can be admitted to hospital as soon as they are diagnosing.	A large number of diagnosed patients need to be admitted to hospital.
After admission, the diagnosed patients are divided into three types: being treated, cured or dying, but the time at this stage is relatively short.	All the diagnosed patients were admitted to hospital after the waiting period, and were discharged in the form of cure or death after admission.
The departments concerned did not take quarantine measures.	In the process of taking isolation measures, latent patients can be divided into three types: undiscovered latent patients, unisolated latent patients waiting for isolation and latent patients who have been related.

3. Establishment of domestic Infectious Disease Model based on SEIR

3.1 Build a two-stage model

The main populations involved are normal person S, latent patient E, confirmed patient I, cured person R and dead person D. We further introduced infectious person F. Normal people have a k probability of being infected by infectious people as latent patients through contact, and latent patients will definitely be diagnosed after the incubation period of d_1~d_2. The diagnosed patient will eventually be cured or die, and neither the healer nor the dead will be infected, but the healer can be contacted by others.

We divide the development of the epidemic in China into two stages:

The first stage is the early stage of the development of the epidemic.After a short period of time and a small number of patients, normal people were diagnosed after the latent period of d_1~d_2. The confirmed patients could be admitted to hospital for treatment once diagnosed, and some of them were still being treated, while others were cured at the rate of α_1 and died at the rate of β_1

In the second stage, the number of patients increased and the government and health departments began to control it. After normal people were infected as latent patients, 1-p of the latent patients were not detected; the proportion of p_1 latent patients was found and needs to be quarantined. Among them, the proportion of p_2 people need to wait n days to be quarantined, but these people will not get sick during this period and will eventually be quarantined. Isolated latent patients and undetected latent patients are diangnosed after latent d_1~d_2. After d_3 days of hospitalization, some of the diagnosed patients were cured with the rate of α_2 and others died with the rate of β_2, but both the cured and the dead were discharged from the hospital.

In addition, the daily contact rate of the lurker is defined as r_1; the daily contact rate of unadmitted patients among diagnosed patients is defined as r_2; the proportion of diagnosed patients admitted to the hospital is defined as γ.

3.2 Epidemic model based on differential equation

In the first stage, it is assumed that the incidence is uniformly distributed among the latent d_1~d_2, then$m = \frac{1}{d_2 - d_1 + 1}$ is average incidence of latent patients. $h_1 = \frac{S(t)}{S(t)+E(t)+R(t)}$ is the rate of contact with normal people. Normal people are less likely to be infected by latent patients, so they can get formula (1) and (2) is in Table 2.

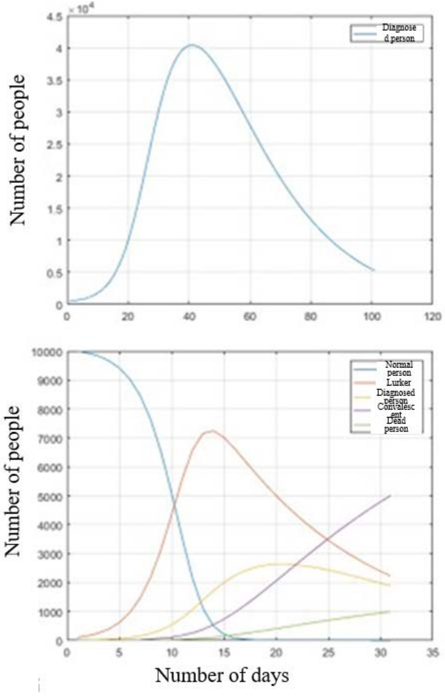
Table 2: Two-stage differential equation model

Stage 1	Stage 2
$\frac{dS(t)}{dt} = -E(1-m)h_1r_1k$ (1) $\frac{d(E)}{dt} = E(1-m)r_1kh_1$ (2) $\frac{dI(t)}{dt} = mE(t) - (\alpha_1+\beta_1)I(t)$ $\frac{dR(t)}{dt} = \alpha_1 I$ $\frac{dD(t)}{dt} = \beta_1 I$ $h_1 = \frac{S(t)}{S(t)+E(t)+R(t)}$ $m = \frac{1}{d_2-d_1+1}$	$\frac{dS(t)}{dt} = -E\left[1-m-p_1(1-p_2)-p_1p_2\frac{1}{n}\right]h_2r_1k$ (3) $\frac{d(E)}{dt} = -E\left[1-m-p_1(1-p_2)-p_1p_2\frac{1}{n}\right]r_1kh_2 - mE(t)$ (4) $\frac{dI(t)}{dt} = mE(t) - \frac{1}{d_3}I$ $\frac{dR(t)}{dt} = \frac{1}{d_3}\alpha_2 I$ $\frac{dD(t)}{dt} = \frac{1}{d_3}\beta_2 I$ $\frac{d(F)}{dt} = E[1-p_1(1-p_2)]h_2r_1k - mF(t)$ $h_2 = \frac{S(t)}{S(t)+E(t)+R(t)}$ $m = \frac{1}{d_2-d_1+1}$

In the second stage, there are quarantined people, so $h_2 = \frac{S(t)}{S(t)+F(t)+R(t)}$ is the new rate of access to normal people, so get formula (3) and (4).

Then similar calculations are made for the relevant parameters of latent patients, confirmed patients, cures, dead people and people with infectious diseases. We can get the following differential equation model as table 2.

The following images are obtained by setting d_1=1, d_2=14, while other parameters are fitted by MATLAB. Bringing in the model results in the figure1 and figure 2.



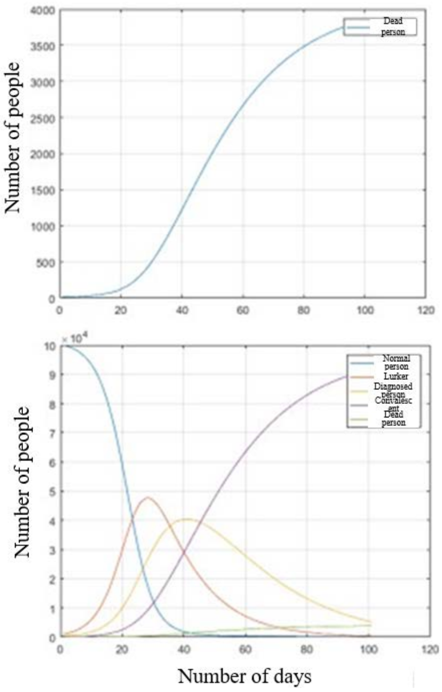


Figure 1: First stage simulation (left)　　*Figure 2: Second stage simulation (right)*

It can be seen from the image that the image of the latent person and the diagnosed person has a unimodal structure, and the peak of the latent person appears obviously earlier than that of the diagnosed person. It shows that both latent patients and suspected patients will have three stages: growth period, peak period and remission period in the development of the epidemic, and the latent patients need to go through a period of latent period to be diagnosed, among which the peak period corresponds to the inflection point of the cumulative confirmed patients. The images of the convalescent and the dead showed the shape of logistic function, which increased slowly in the initial stage and increased rapidly in the outbreak period. It can be divided into three stages: the long stage and the late stage. The above analysis is in line with the reality.

At the same time, the picture on the right is a simulation model of the second stage based on the first stage. Compared with the high infectiousness simulation of the first stage on the left, the increase in the number of people infected will slow down and the increase in the number of latent patients will slow down. It reached a peak shortly after the stage, the number of recovered patients increased significantly, the mortality rate decreased, and the rate of infection of normal people also significantly slowed down. It shows that my country's later epidemic prevention measures are more effective.

4. Comments on China's national defense measures based on the model

We define a basic infection number $R_0$to measure how many people can be infected by each person with infectious ability during the entire infectious disease period in an environment without external interference and immunity.

$$R_0 = rkT, T \sim U(d_1 - d_2) \tag{5}$$

If there is no human control, $r = r|_{t=t_0} = 1.43, k = k|_{t=t_0} = 0.5$ is fitted by matlab.

$$R_0 = rkE(T) = 1.43 \times 0.5 \times 0.75 = 5.3526 \tag{6}$$

Based on the second stage model of China's epidemic development established in the above question 1, under China's prevention and control measures, the fitting can be obtained:

$$R_0 = rkE(T) = 1.43 \times (1 - 30\%) \times 0.5 \times (1 - 32\%) \times 0.75 = 2.55255 \tag{7}$$

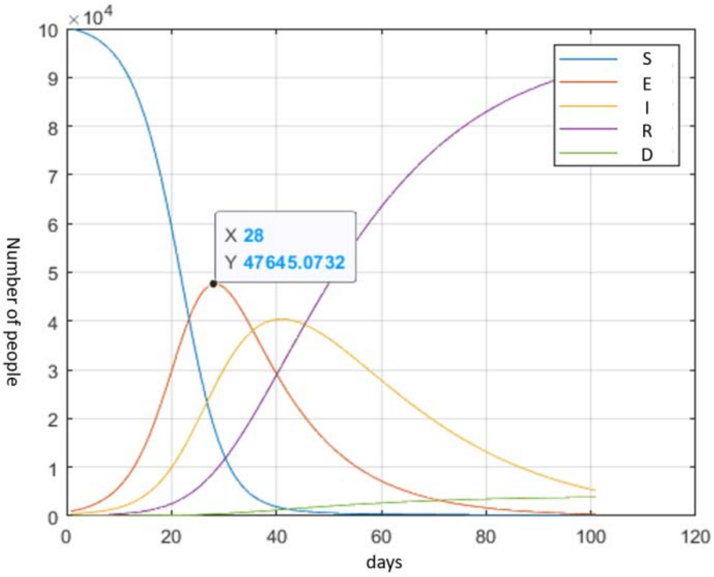


Figure 3: Simulation map of my country's epidemic situation

It can be seen that China closed the city on January 23 and adopted measures such as wearing masks and disinfection, which reduced the infection success rate by 32%; the government required a home isolation policy to reduce the daily contact rate by 30%.

5. Conclusion

In this paper, around the COVID-19 epidemic model, based on the SEIR model, the epidemic transmission process is divided into two stages. According to these two stages, the improved infectious disease model based on SEIR model is established, and we analyze five kinds of people: a normal person, latent person, confirmed diagnosis, cure and death, and introduce infectious people to assist analysis. At the same time, we comparing the size of R_0 in the two cases of China's unmanned intervention and related prevention and control measures, it is finally concluded that China's prevention and control measures will basically spread. The dye count dropped from 5.3625 to 2.55255.

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