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A Survey on the Applications of SIR Model in COVID-19

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Abstract. Since December 2019, COVID-19 has spread rapidly around the world. As an acute respiratory infectious disease, it has seriously affected people's health and daily life. Currently, the prevention and control of COVID-19 is still very important. In this paper, literature was retrieved through PubMed, Wanfang Data Knowledge Service Platform and VIP Information Chinese Journal Service Platform. Starting from the hazards of COVID-19 and the application of current infectious disease transmission models, the application of SIR model in the transmission of COVID-19 was reviewed, and the influencing factors of COVID-19 transmission and corresponding prevention and control measures were analyzed, in order to provide more scientific and effective suggestions for the follow-up prevention and control of the epidemic.

Keywords. SIR model, COVID-19, prevention and control measures

1. Introduction

COVID-19 was first identified in Wuhan, China, in December, 2019. In terms of mortality and infection rate, COVID-19 is considered to be the most serious epidemic since the influenza pandemic at the beginning of the 20th century. The main transmission routes of COVID-19 this time are respiratory spray transmission, aerosol transmission and contact transmission. Although we have entered the post pandemic era, it is crucial to analyze and assess the spread of COVID-19 for prevention and control measures on the epidemic diseases [1-3].

2. Application of infectious disease model in COVID-19

For different infectious diseases, it is necessary to construct appropriate infectious disease models based on their transmission principles. Therefore, finding out the pathogenesis of COVID-19 and its transmission mechanism in the population, and establishing appropriate models can restore the transmission law of this infectious disease. Since the outbreak of COVID-19, several studies based on dynamics models of infectious diseases and related data have analyzed the epidemic development, simulated the epidemic development trend in different regions of China, predicted the

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infections number and put forward relevant suggestions for epidemic prevention and control [4-5].

Li Qun [6] collected the data of 425 cases that first appeared, summarized the disease characteristics of the cases, and estimated the basic reproduction number of COVID-19 virus. CHAN [7] discovered second-generation infectious disease cases and pointed out that the main transmission characteristic of the virus is 'human to human'. Through analyzing the source of the cases, he first proposed the occurrence of cases outside the South China seafood market. Wang Guoqiang [8] et al. established a discrete age structure COVID-19 model by studying the contact pattern of people of different ages, fitting the cumulative number of cases, calculating the extinction time and other corresponding biomass through Monte Carlo numerical algorithm (MCMC), and found that there is obvious age heterogeneity in infected people, and the elderly and young people should improve their awareness of prevention and control. WeiXia [9] et al. analyzed the transmission potential of 50 infection clusters in the incubation period by collecting the demographic characteristics, contact history, symptom onset date and other data of the confirmed cases, and confirmed that COVID-19 can be transmitted to close contacts in the incubation period. Anna L. Ziff [10] used the fractal dynamics method to conduct epidemiological research and was widely used in the epidemiological research of COVID-19. Researchers identified three stages of disease transmission through the number of deaths, namely, exponential growth, power law distribution and exponential decline of daily mortality. Liu Jianxiang et al. [11] considered the diverse and spatiotemporal characteristics of epidemic data and constructed a visualization model of the epidemic that includes situation analysis, source analysis, transmission mode analysis, and trend prediction. This model more intuitively reflects the dynamics of the epidemic and analyzes and evaluates corresponding government measures through the method of time axis interaction. Xiao Wenlei [12] established a cybernetics based on a dynamic infection model of COVID-19 to simulate its infection mechanism and development trend in cities, and calculate the number of infected people in closed cities. Chimmula and Zhang [13] used the Long Short Term Memory (LSTM) network to predict the COVID-19 outbreak in Canada, which identified as the key characteristics of estimating the Canadian pandemic trend. Salgotra and Gandomi [14] set up two prediction models on genetic algorithm and the results for COVID-19 cases in India showed the model is highly reliable. Chakraborty and Ghosh [15] used regression tree algorithm to make real-time prediction and carried out risk assessment of COVID-19 in some serious countries.

3. Application of SIR model in COVID-19

SIR(Susceptible Infected Recovered, SIR) model is one of the most classic mathematical models for the dynamics of infectious diseases. In the model, the population within the epidemic range of infectious diseases is divided into three categories: susceptible (S), infected (I), and displaced (R). And based on the differential equations, the law of the population changes over time in each region is studied [16]. In order to understand the development trend of COVID-19 more intuitively, researchers have used SIR models to build the epidemic spread.

3.1. Study on the COVID-19 spread with SIR model

Anas [17] mentioned that SIR model about the COVID-19 epidemic can be used to deduce the transmission degree of infectious diseases at any time, depending on the susceptible people number reduced by vaccination. For the number of infected persons, measures such as home isolation and timely isolation can be taken and the disease transmission rate of each contact is the most influential aspect of hand hygiene and wearing masks. Zhou et al [18] calculated the basic reproduction number of COVID-19 and made a simple development prediction based on SEIR model. It verified that the early transmission ability of COVID-19 was slightly higher than that of SARS and was a controllable infectious disease with moderate to high infection rate. Yin Nan [19] conducted a simulating analysis of the COVID-19 spread in a limited area with SIR model. The experimental simulation was divided into three aspects: the average infected number, group cross infection and contact infection. It was concluded that controlling the spread of COVID-19 at a critical point would effectively control its infection to the offspring, prevent the epidemic from spreading exponentially, and put forward relevant countermeasures. Fanruguo et al [20] improved SEIR model to predict the inflection point of the epidemic under three different incubation periods. The study output was basically consistent with the real epidemic development. It was a good guiding role for accurate epidemic prevention and control.

3.2. Study on the COVID-19 spread with improved SIR model

Meiwenjuan et al. [21] combined extreme learning machine with SIR model to build a new extreme real-time prediction model, which can effectively provide data analysis for COVID-19 in real time. Weiyongyue et al [22] established SEIR&CAQ transmission dynamics model and used it to fit official data. It was found that the fitting results were smaller and closer to the real data, which could be applied to the trend prediction of epidemic situation. Chen [23] et al have summarized a parameter estimation method using improved hybrid Nelder Mead simplex search and particle swarm optimization and changed the traditional SIR model into a general fractional SEIAR model to analyze the real data. The method constructed a simple and effective analysis method, which has the characteristics of reflecting memory effect, capturing fractal, multi-scale nature, good fitting effect and so on. It is easy to popularize and apply and helpful to guide relevant departments to prevent, control and even predict the outbreak of infectious diseases. Zhang Yanxia and Li Jin [24] improved the SIR model and constructed differential equations to simulate the COVID-19 spread through the improved SIR model and Runge Kutta method. They calculated the relationship between the various groups over time and predicted the epidemic spread, compared the SIR prediction results with the actual situation to verify the isolation method for reducing the daily contact rate. Sheng Huaxiong and others [25] combined the SIR model with the logistic model to model and analyze the changes in the infected people number during the epidemic transmission in Wuhan from the control stage to the free transmission stage. They depicted the changes of various populations over time in the control stage, used the logistic model to compare the influence of different control measures and concluded the importance of timely epidemic prevention measures in the free transmission stage. Yu Zi et al [26] chosed the improved time-varying parameter SIR model to simulate the changing trend of the COVID-19 epidemic in different stages and predicted the inflection point of the epidemic and the maximum number of confirmed cases to evaluate the effect of prevention and control measures. Linjunfeng [27] added 'invisible disseminator' on the traditional SEIR model and the results reflected the effective of nucleic acid detection and other technologies. Dos et al [28] proposed a dynamic map to describe the COVID-19 epidemic on the classical SEIR differential model with vaccinated population, which can describe three population dynamics: newly infected population, cumulative infected population and vaccinated population. The model has reduced the number of variables, made it easy to adjust parameters, and used analysis tools to define useful information. Chen [29] and others mentioned some challenges faced by SEIR model at present and put forward corresponding suggestions.

4. Conclusions

In conclusion, mathematical models have made great contribution in the prevention and control of infectious diseases, among which SIR model is more general. SIR model is feasible, and has great practical and scientific significance. It can not only macroscopically describe the epidemic situation and extrapolate data, but also dynamically track the daily contact rate and daily removal rate. The SIR model can simulate and predict the epidemic trend of COVID-19, provide real-time data analysis for the epidemic, provide more targeted countermeasures and suggestions to strengthen epidemic prevention and control and guide the precise prevention and control of the epidemic.

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