Study on Epidemic Prevention and Control Strategy of the Capital Public Security Organs Under the Normalized Epidemic Prevention and Control Based on the SEIR Model

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Abstract: Based on the data of COVID-19 epidemic situation in Beijing in 2020, a modified SEIR epidemic dynamics complex network model was established to analyze the trend of the epidemic situation in the capital and evaluate the effect of prevention and control measures. Considering that COVID-19 has latent period, strong infectivity and normalized epidemic prevention and control measures, a modified SEIR model with medical tracking and isolation measures was established and its dynamic parameters were estimated. Based on parameter estimation, the strength of epidemic prevention and control measures in Beijing was evaluated, and the impact of isolation measures based on reducing the contact rate of infected persons and increasing the isolation ratio on the development of epidemic situation was evaluated. Based on the responsibilities of the capital public security organs under the normalization of epidemic prevention and control, this paper studies the key work of the capital public security organs under the normalization of epidemic prevention and control.

Keywords: normalization of epidemic prevention and control; COVID-19; SEIR model; public security organs

1. Introduction

Since the outbreak of COVID-19 in Wuhan, Hubei Province, the capital, as a city with high population mobility, has experienced significant epidemic growth for two times. The first epidemic was mainly imported cases in Hubei Province. Beijing was closed in January 23, 2020 and strict isolation prevention and control measures were adopted to effectively control the epidemic before a large-scale outbreak. There were accumulatively 411 cases and 9 deaths. The global pandemic of COVID-19 started in March 2020. Against such background, it is difficult for China to detach itself from the world. In particular, Beijing, as the national political, economic, cultural, and technological exchange center, faces daunting task of preventing and controlling the epidemic. Since entry into the stage of normalized epidemic prevention and control, Beijing adheres to the principle of "prevention of external imported cases and internal proliferation". The first local case occurred in Beijing on June 11, 2020, which then spread rapidly afterwards. Since the epidemic originated in the Xinfadi vegetable wholesale market in Fengtai District, it was called the "Xinfadi epidemic". The prevention and control departments at all levels in the capital make quick deployment, perform strict isolation prevention and control, adopt medical follow-up isolation measures for precise prevention and control, and centralized treatment. The epidemic is thus timely controlled without affecting the normal work and travel of citizens in low-risk areas in the capital. The Xinfadi epidemic lasted for nearly two months, with a total of 335 cumulative cases and 0 deaths.

2. Research Overview on COVID-19 Epidemic Prediction and Trend Analysis Home and Abroad

Based on statistical models, epidemic dynamics models and artificial intelligence algorithms, etc. there are abundant research results relating to predictive analysis of COVID-19. Literature [1] estimates the COVID-19 epidemic scale and virus incubation period based on the Logistic growth curve. Literature [2-3] predicts the transmission risk of COVID-19 based on the modified SEIR complex network model. On the basis of literature [2-3], literature [4] takes SEIR model to predict when the cities around Wuhan can resume work. Literature [5] predicts the inflection point of COVID-19 in Wuhan based on the SEIR model. Based on the modified SEIR model, literature [6] estimates the COVID-19 epidemic, and evaluates the epidemic development trend under isolation prevention and control measures of different intensities. In addition, some scholars simulate the epidemic data using AI algorithms, with some results achieved. Based on the above-mentioned literature, this paper collects data on Xinfadi epidemic, then, based on the modified SEIR model, analyzes the development trend of Xinfadi epidemic in Beijing, evaluates the effects of normalized epidemic prevention and control measures, and studies responsibility of public security organs in the normalized epidemic prevention and control.

3. Data, Model and Parameter Estimation

3.1 Data source

The data of this model are mainly based on Xinfadi epidemic in Beijing from June to July 2020, which are sourced from the daily epidemic data reported by the Beijing Municipal Health Commission [7], including newly confirmed cases, cumulative confirmed cases, data of close contacts still under medical observation, reported death cases, and recovered cases. It should be noted that the epidemic in Beijing in January 2020 was mainly triggered by spread of imported cases in Hubei Province. The country has not yet entered the stage of normalized epidemic prevention and control. This paper assesses the intensity and effectiveness of the capital's epidemic prevention and control measures under normalized epidemic prevention and control. It then arranges key jobs of the public security organs in the normalized epidemic prevention and control stage, so Xinfadi epidemic data from June to July 2020 is taken as the research object.

3.2 Modified SEIR model

The modified SEIR model considers the virus transmission ability of exposed patients and the correction effect of follow-up isolation interventions on the epidemic. Based on the actual epidemic data in the capital, this paper refers to some parameters in literature [4] in light of actual conditions, performs data fitting on SEIR model parameters inconsistent with Wuhan epidemic data. It then analyzes the epidemic in Hubei Province through Euler's numerical method, discusses the impact of prevention, control, isolation and centralized admission measures on the epidemic development.

The classic SEIR model divides the population into susceptible (S), infected (I), exposed (E), and recovered population (R). Considering the isolation measures to prevent and control infectious diseases, the population groups in the model are newly added with isolate susceptible persons S_q, isolate exposed persons E_q, and isolate infected persons I_q. Where, the isolate infected persons will be immediately sent to designated hospitals for isolation and treatment, so the isolate exposed persons E_q and isolate infected persons I_q are all transformed into hospitalized patients H. In the classic SEIR model, S, I, E respectively refer to susceptible persons, non-isolated infected persons, and exposed persons that are missed by the isolation measures. Isolate susceptible persons are transformed into susceptible persons again after the isolation is lifted, while the infected and exposed persons have varying degrees of ability to infect susceptible persons and turn them into exposed persons. The population conversion is shown in Figure 1.

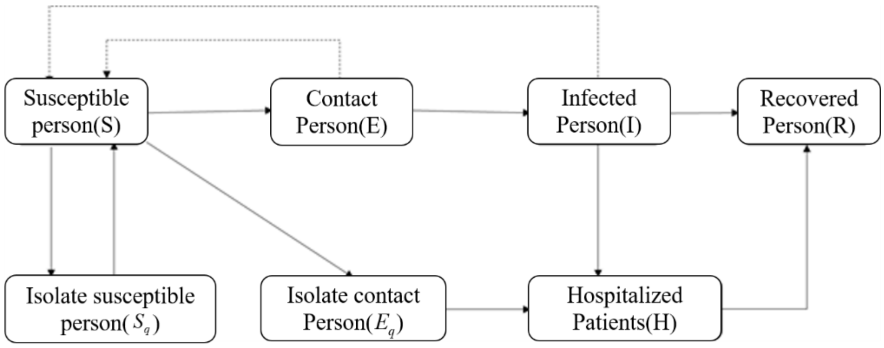

Figure 1. population conversion in the modified SEIR model

The modified SEIR model equation is constructed as follows [6]:

$$\begin{cases} dS/dt = -[c\beta + cq(1-\beta)]S(I+\theta E) + \lambda S_q \\ dE/dt = c\beta(1-q)S(I+\theta E) - \sigma E \\ dI/dt = \sigma E - (\delta_I + \alpha + \gamma_I)I \\ dS_q/dt = cq(1-\beta)S(I+\theta E) - \lambda S_q \\ dE_q/dt = c\beta q S(I+\theta E) - \lambda S_q \\ dH/dt = \delta_I I + \delta_q E_q - (\alpha + \gamma_H)H \\ dR/dt = \gamma_I I + \gamma_H H \end{cases} \quad (1)$$

3.3 Parameter estimation based on Xinfadi epidemic data

The parameters of the above model are estimated. Since the infection probability β and mortality α of the infected persons in each region are basically unchanged, the values are consistent with the those in the literature [4,6]. The parameters δ_I and δ_q reflect the centralized admission capacity of patients in a region. Given the relatively uniform centralized admission capabilities in various regions at present, the value is consistent with the value in the literature [4,6]. The ratio of transmission capacity of exposed persons to that of infected persons is θ=1 (assuming that the two populations have equal transmission capacity). The isolation release rate $\lambda = 1/14$ (Isolation period is 14 days), the conversion rate of exposed persons to infected persons is $\sigma = 1/5.5$ (incubation period is 5.5 days according to literature [1]). Other parameters are estimated using Euler's numerical method based on the Xinfadi epidemic data in the first 28 days (June 14 to July 12). The selection of initial model simulation values is shown in Table 1, and the parameter estimates are shown in Table

Table 1. Selection of initial model simulation values in epidemics

Variable	S	E	I	S_q	E_q	H	R
Value (June 13)	21.536 million	140	106	139	20	63	0
Value description	Officially released data on Beijing's permanent resident population	The difference between the number of confirmed cases on June 19 and that on June 14.	The officially released data on cumulative confirmed cases on June 14	The officially released data on cases under medical observation on June 14	Estimate, which is smaller than the cases under medical observation	$I + E_q$, isolate cases and some cases under medical observation	Officially released data on recovered persons on June 14

Data source: Beijing Municipal Health Commission. Prevention and control of pneumonia epidemic caused by COVID-19 infection. Epidemic Notification. http://wjw.beijing.gov.cn/wjwh/ztzl/xxgzbd/gzbdyqtb/.

Table 2. Estimation of some parameter values and some parameter assignments based on epidemic data

Parameter	**Parameter Value of Xinfadi Epidemic**	**Parameter Definition**	**Value Source**
c	0.88	contact rate of infected persons	Parameter estimation
q	8.91*10e-4	isolation ratio	Parameter estimation
δ_I	0.13	Isolation rate of infected persons	Literature [4]
δ_q	0.13	The conversion rate of isolate exposed persons to isolate infected persons	Literature [4]
γ_I	0.001	Recovery rate of infected persons	Parameter estimation
γ_H	0.001	Recovery rate of isolate infected persons	Parameter estimation
β	2.1*10e-8	infection probability of infected persons	Literature [4]
α	2.7*10e-4	Mortality	Literature [4]
θ	1	The ratio of transmission capacity of exposed persons to that of infected persons	The transmission capacity of the two populations is equal
λ	1/14	Isolation release rate	The isolation period is 14d
σ	1/5.5	The conversion rate of exposed persons to infected persons	Literature [错误!未定义书签。]

The estimated values of some model parameters are shown in Table 2. The recovery rate γ_I in this model and the recovery rate of isolate infected persons are low. For its reason, we timely discovered the epidemic, and the number of patients who recovered or discharged in the early stage was 0, so these two parameters have small fitting values. In this model, the average exposure coefficient $c = 0.88$ is smaller than most of the parameter estimates in literature [4, 6], and far smaller than the estimates of Wuhan data. To a certain extent, it shows that the capital control, prevention and isolation are effective and precise thanks to the normalized epidemic prevention and control measures. The parameter isolation rate $q = 8.91*10e-4$ is greater than most of the parameter estimates in literature [4,6], which suggests that the medical follow-up isolation measures of the capital departments at all levels are also quite strict.

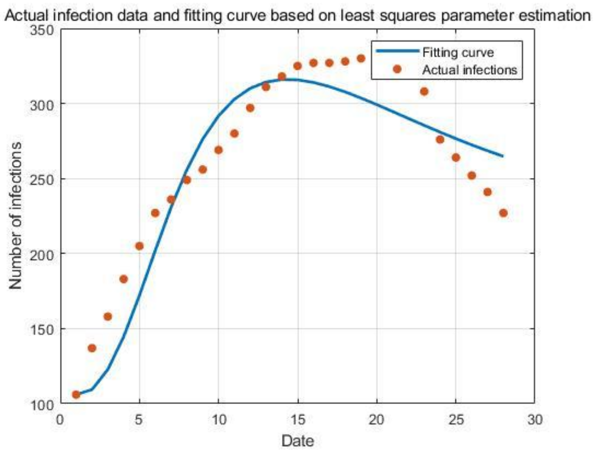

Figure 2. Parameter estimation and fitting effect diagram of Xinfadi epidemic data

The simulated epidemic data and actual epidemic data based on parameter estimation are shown in Figure 2. It can be seen from the figure that, most of the fitted data before June 25 are smaller than the actual data. This is because the infected persons in the sample data are all existing infected persons, the infected persons in the model are non-isolated infected persons with a number smaller than the sample data. Therefore, the fitted value in the curve is smaller than the actual data value (access to non-isolated infection data sample is difficult). The tail fitted value is higher than the actual value because the recovery rate in the later period tends to be normal, and the lower recovery rate curve in the early period will overtop the actual data value.

4. Epidemic Prevention and Control Measures based on the Isolation Ratio q and the Contact Rate c of Infected Persons

4.1 The impact of the isolation ratio q on the epidemic and corresponding epidemic prevention and control measures

Figure 3 simulates the intensity of follow-up isolation measures based on the impact of reduction in the parameter isolation ratio q on the epidemic evolution. Changes in the isolation ratio q have a more obvious impact on the epidemic. The reduction in the isolation ratio q leads to rapidly expanded epidemic scale, with peak value shifted backward. When the value q is reduced to 0.5 times that of the original, the epidemic scale is twice that of the original, with peak shifted backward by about 5 days.

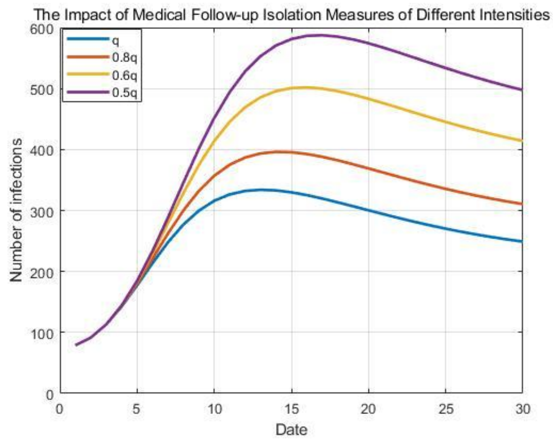

Figure 3. The impact of medical follow-up isolation measures of different intensities on the epidemic trend

Prevention and control measures based on the isolation ratio q mainly include medical follow-up isolation and centralized isolation treatment. From the above analysis, it can be seen that strict medical follow-up isolation measures and centralized isolation treatment are effective means to reduce the epidemic scale and shorten the epidemic course, thus important measures to control the epidemic. For example, in the Xinfadi epidemic, Xinfadi practitioners and close contacts of patients are isolated for 14 to 28 days, and those who have been to Xinfadi within 14 days are isolated at home for 14 days.

4.2 The contact rate c of infected persons, its impact on the epidemic and the corresponding epidemic prevention and control measures

Parameter fitting in the model is based on the current contact rate $c = 0.88$ under the current prevention, control and isolation measures. The development trend of Xinfadi epidemic under weaker prevention and control isolation measures is simulated by increasing c to evaluate the effect of epidemic prevention and control isolation. Figure 4 simulates epidemic trend under higher contact rate. It can be seen that the epidemic has been well controlled under the current prevention and control at all levels. However, under a higher contact rate, the epidemic will develop more rapidly with more infected persons, which may cause greater panic in society and hinder resumption of work in various sectors.

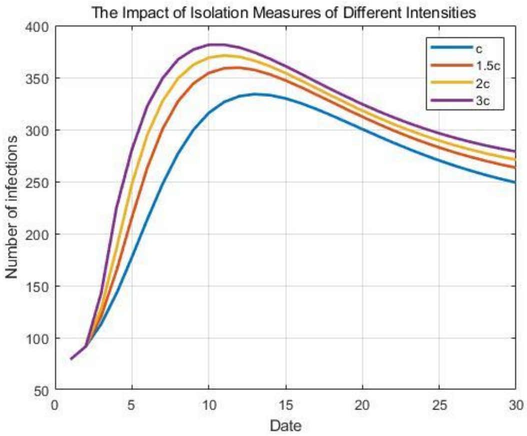

Figure 4. Assessment of the impact of isolation measures of different intensities on Xinfadi epidemic

The epidemic prevention and control measures based on reduction in contact rate c of infected persons mainly include isolation at home, personal health protection, and traffic control, which illustrates the importance of isolation at home, personal safety protection, and traffic control in controlling the epidemic scale and slowing the epidemic development.

5. Public Security Organs' Epidemic Prevention and Control Strategies Based on the SEIR Model

Based on the SEIR model, we can see the importance of medical follow-up isolation, centralized isolation treatment, isolation at home, personal health protection, and traffic control to normalized epidemic prevention and control. According to the "Law of the People's Republic of China on the Prevention and Control of Infectious Diseases", isolation measures that restrict personal freedom include isolation treatment, medical observation and general isolation measures, which endows medical institutions and public security organs with the power of enforcement. In addition, traffic control is also an important prevention and control measure based on contact rate reduction, which is a duty of the public security organs in the law enforcement process. Also, the public security organ should actively guide residents in personal health protection. In the capital's epidemic prevention and control, the main responsibilities of the capital's public security organs include epidemic prevention, control and stability maintenance, traffic control, epidemic-related public opinion guidance, and crackdown on epidemic-related illegal crime.

The first is unified command and linkage of various departments (see Figure 5). In the epidemic prevention and control work of the Public security organs, by establishing the Municipal Epidemic Prevention and Control Command Center, the public security organs establish the linkage mechanism between various departments of the capital public security organs to achieve precise prevention and control via scientific deployment of police forces based on big data technolog.

The second is to strengthen prevention, control and stability maintenance of key places. Strengthen the prevention, control and stability maintenance of centralized medical follow-up isolation points, centralized isolation treatment points, hospitals, medium and high-risk streets, communities and other key places. For behaviors such as resisting epidemic prevention and control, disobeying epidemic prevention and control decisions, not cooperating with investigations, testing and isolation measures, resisting epidemic prevention and control, violently damaging doctors, suffering or suspected of having COVID-19, deliberately concealing the condition, refusing to accept isolation, compulsory isolation or treatment, public security organs shall control it or forcibly enforce measures according to law to ensure implementation of major epidemic prevention and control measures such as medical follow-up isolation, prevention and control isolation, thereby guaranteeing timely discovery, rapid disposal, precise prevention and control, and effective treatment of the epidemic.

The third is to strengthen cross-regional and cross-city traffic control. Combine departments such as highway checkpoints, subways, public transportation sectors, strengthen health inspections of travellers based on big data technology, restrict the passenger capacity of some transportation means, temporarily close high-risk traffic lines, and prevent the epidemic spread to secondary risk areas. For the capital checkpoints on passengers in and out of Beijing, there is need to join highway departments to strengthen verification of passers-by, strictly prohibit the entry and exit of people from medium and high-risk areas, thus preventing spread of the epidemic across cities.

The fourth is to strengthen the public opinion guidance of public security organs. Strengthen the coordination between multiple police types within the public security organs. Combine public opinion handling functions of intelligence, cyber security, national security, grassroots police stations, work together with departments like the political department, office, news office to integrate and optimize the functions. Establish a cross-departmental coordinated operation mechanism, and start analysis, research and judgment of public opinion on epidemics in a timely manner to achieve rapid disposal and guidance. Strengthen cooperation with social organizations, media and other departments, cooperate with Internet operators, private organizations, media industry, etc., to seek information and intelligence sharing, strengthen public opinion monitoring, and establish information exchange mechanism against major emergencies and joint information release mechanism against the epidemic.

References

[1] Qiu, M. Y.; Hu, T.; Cui, H. J.; Parametric Estimation for the Incubation Period Distribution of COVID-19 under Doubly Interval Censoring. Acta Mathematicae Applicatae Sinica **2020**, 43(02), 200-210.

[2] Tang, B.; Wang, X.; Li. Q.; et al. Estimation of the transmission risk of the 2019-nCoV and its implication for public health interventions. J Comput Math **2020**, 9: 462.

[3] Tang, B. Bragazzi, N. L.; Li, Q.; et al. An updated estimation of the risk of transmission of the novel coronavirus

(2019-nCoV). Infect Dis Model **2020**, 5: 248–255.
[4] Wang, X.; Tang. S. Y.; Chen, Y.; Feng, X. M.; Xiao, Y. N.; Xu, Z. B.; When will Wuhan and surrounding areas resume work under the COVID-19 epidemic? Data-driven network model analysis. SCIENTIA SINICA Mathematica **2020**, 50(07):969-978.
[5] Fan, R. G.; Wang. Y. B.; Luo, M.; Zhang, Y. Q.; Zhu, C. P.; COVID-19 transmission model and inflection point prediction based on SEIR. Journal of University of Electronic Science and Technology of China: 1-6 [2020-08-22].http://kns.cnki.net/kcms/detail/51.1207.T.20200221.1041.002.html.
[6] Cao, S. L.; Feng, P. L.; Shi, P. P.; Study on the epidemic development of COVID-19 in Hubei province by a modified SEIR model. Journal of Zhejiang University (Medical Sciences), **2020**, 49 (02):178-184.
[7] Beijing Municipal Health Commission. Prevention and control of pneumonia epidemic caused by COVID-19 infection. Epidemic Notification. http://wjw.beijing.gov.cn/wjwh/ztzl/xxgzbd/gzbdyqtb/.