Journal of Biostatistics and Epidemiology

J Biostat Epidemiol. 2020;6(2): 101-106

Original Article

SIR Model for Estimations of the Coronavirus Epidemic Dynamics in Iran

Maryam Deldar[1], Samaneh Tahmasebi Ghorabi*[2], Kourosh Sayehmiri[3]

[1]Department of Biostatistics, Ilam University of Medical Sciences, Ilam, Iran.
[2]Department of Public Health, Ilam University of Medical Sciences, Ilam, Iran.
[3]Department of Biostatistics, Faculty of Health, Ilam University of Medical Sciences, Ilam, Iran.

ARTICLE INFO

Received 14.05.2020
Revised 01.06.2020
Accepted 17.06.2020
Published 20.06.2020

Key words:
Coronavirus;
Epidemic;
Covid-19;
SIR model;
Iran

ABSTRACT

Background: The Coronavirus 2019-nCOV (COVID-19) epidemic by SARS-CoV-2 is spreading worldwide, and by March 1, 2020, 67 countries, including Iran, have been affected. Many studies are being conducted at home and abroad to predict the outbreak of the disease so that they can make the necessary medical and health decisions in a timely manner.

Methods: we used the SIR model to identify parameters to calculate epidemic features and some estimates of the new coronavirus. Data on the transmission of the novel coronavirus were extracted from the GitHub source in the covid19.analytics software package.

Results: According to our model estimates, the rate of infection $\beta = 1$ and the rate of removal $\gamma = 0.667$ and index R0 = 1.497 were obtained. Because the value of R0 is more than one, it is still an epidemic disease. Given that tfinal~132 days was estimated, we can expect the transmission of this epidemic to stop in Iran after July 3, 2020, provided that existing quarantine measures and patient isolation rates continue as usual. In comparison with the global SIR model, we reached the peak of the infection earlier than the global model, but in improved and susceptible cases, we performed better than the global model. The graph of recovered and susceptible cases in Iran earlier than the global model cut off themselves.

Conclusion: Forecasts are set to be a useful guide for deciding whether to transfer COVID-19. According to the predictions and estimates made, more attention should be paid to control measures.

Introduction

Emerging infectious diseases, such as severe acute respiratory syndrome(SARS) and Zika virus disease, present a major threat to public health. Despite intense research efforts, how, when and where new diseases appear are still a source of considerable uncertainty (1, 2). Since December 31 2019, the 27 cases of unknown pneumonia were reported in Wuhan City of Hubei Province in South China (3). On 7 January 2020, Chinese government and the World Health Organization(WHO) identified a novel coronavirus (2019-nCoV) as the causative virus, which belongs to the same virus family of the SARS that outbreak also in South China in 2002-2003 (4). Since about 23 Jan 2020, the Chinese Government has taken strong measures, to prohibit the virus's transmission, such as warning citizens from going outdoors, temporarily suspending the public transport between some big cities, and even taking quarantine for the main infected city (3). On 30 January 2020, The WHO declared the coronavirus novin-2019 epidemic as a public health emergency with international concern (5). On February 11 2020, WHO officially named disease caused by Corona Virus novin-2019 as the Coronavirus disease (covid-19) (5).

* .Corresponding Author Email: samaneh.tahmasebi70@gmail.com

Please cite this article in press as Deldar M, Tahmasebi-Ghorabi S, Sayehmiri K. SIR Model for Estimations of the Coronavirus Epidemic Dynamics in Iran. *2020;6(2): 101-106*

Epidemiological investigations have suggested that the outbreak was associated with a seafood market in Wuhan (1). The WHO report also states that the Coronavirus novin-2019 has been identified in environmental samples collected from the Hanan seafood market (6).

Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. older people, and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness. According to guidelines of the WHO, most common symptoms of corona disease include: fever, dry cough, tiredness. Less common symptoms: aches and pains, sore throat, diarrhea, conjunctivitis, headache, loss of taste or smell, a rash on skin, or discoloration of fingers or toes (7).

Mathematical modelling has gained more attention and awareness in epidemiology and the medical sciences. One family of these models is the dynamical epidemic model called Susceptible-Infected-Removed(SIR) model (8). The SIR model originated from the study of the plague almost one hundred years ago (9). SIR Model is a mathematical model for showing disease epidemics obtained by solving differential equations (10). The model is for the process of transmitting new coronavirus infection based on data from infected persons, discharged patients and discharged patients in the period of quarantined and sensitive populations (11). SIR models and statistical methods perform parameter identification to calculate epidemic features and some estimates (10).

Studies have been conducted using the SIR model in different parts of the world, including the Nesteruk's study in South Korea that The known SIR model, statistical approach to the parameter identification and the official WHO daily data about the confirmed cumulative number of cases in the Republic of Korea were used to calculate the SIR curves and make some estimations (10). In another study in China, Tang et al, the SIR model for novel coronavirus-infection transmission process was used based on the data of the infected persons, discharged patients and discharged patients during the period of isolation and control in Wuhan. Least squares estimation method was used to estimate the key parameters of the model (11).

In the Zhou Tang study in China, a modified SEIR(Susceptibility-Exposure-Infection-Removal) model is used to predict and analyze the changing trend of the epidemic situation and estimate the parameters involved, and then used MATLAB to simulate and analyze the results (12). Zhang et al made an early prediction of the 2019-nCoV outbreak in China based on a simple mathematical model and limited epidemiological data (3). Based on the SIR model, we made a simple prediction of the coronavirus infection trend in Iran and estimated the time to end of infection by estimating the parameters.

Method

Data

Data on the transmission of the novel coronavirus infection in this paper were selected from date 2020/01/22 to 2020/04/28 of the GitHub source in the covid19.analytics package. These data were matched with the daily data of the WHO.

Table 1. Official cumulative numbers of confirmed coronavirus cases in Iran

Date	Accumulated number of cases in Iran	Date	Accumulated number of cases in Iran	Date	Accumulated number of cases in Iran
19-Feb	2	14-Mar	12729	7-Apr	62589
20-Feb	5	15-Mar	13938	8-Apr	64586
21-Feb	18	16-Mar	14991	9-Apr	66220
22-Feb	28	17-Mar	16169	10-Apr	68192
23-Feb	43	18-Mar	17361	11-Apr	70029
24-Feb	61	19-Mar	18407	12-Apr	71686

25-Feb	95	20-Mar	19644	13-Apr	73303
26-Feb	139	21-Mar	20610	14-Apr	74877
27-Feb	245	22-Mar	21638	15-Apr	76389
28-Feb	388	23-Mar	23049	16-Apr	77995
29-Feb	593	24-Mar	24811	17-Apr	79494
1-Mar	978	25-Mar	27017	18-Apr	80868
2-Mar	1501	26-Mar	29406	19-Apr	82211
3-Mar	2336	27-Mar	32332	20-Apr	83505
4-Mar	2922	28-Mar	35408	21-Apr	84802
5-Mar	3513	29-Mar	38309	22-Apr	85996
6-Mar	4747	30-Mar	41495	23-Apr	87026
7-Mar	5823	31-Mar	44606	24-Apr	88194
8-Mar	6566	1-Apr	47593	25-Apr	89328
9-Mar	7161	2-Apr	50468	26-Apr	90481
10-Mar	8042	3-Apr	53183	27-Apr	91472
11-Mar	9000	4-Apr	55743	28-Apr	92584
12-Mar	10075	5-Apr	58226		
13-Mar	11364	6-Apr	60500		

Statistical analysis

SIR Model is a mathematical model for showing the epidemic of diseases that is obtained by solving differential equations. Susceptible people (S) are people who have not yet been infected and may be infected with the virus at any time. People with infection (I) are people who are sick and can spread the virus. Removed people (R) include people who have isolated, recovered, died, and those who do not spread the infection. The number of victims we show with V is equal to the number of people infected and eliminated: in other words, V = I + R, the intensity of removal ($\boldsymbol{\Upsilon}$), as one of the important parameters of SIR model, shows the ratio of treated and dead patients (10, 13, 14). Intensity of infection (β) and intensity of removal ($\boldsymbol{\Upsilon}$) are calculated according to the following formulas:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \Upsilon I$$

$$\frac{dR}{dt} = \Upsilon I$$

The total population of the area where the epidemic occurred is denoted by N, therefore N=S+I+R In this work, we considered the total population of Iran (approximately 81,800,000) as N, I0 = 1, S0 = N-1, R0 = 0. Due to the high complexity of the process of calculating the differential equations, the software R.ver.3.6.2 was used to process the data, estimate the value of the parameter and predict the model.

Results

The novel coronavirus is well compatible with the SIR model. The accuracy of the new model is almost good. The model shows that we reached the peak of the infection on the 47th day after the onset of infection, that is, on 2020/04/08. The number of removal cases (R) that decrease from susceptible population (S), increases slightly from the fortieth day after the outbreak, and then increases continues. Almost on the same date, the recovered cases increased slightly and then increased continues, and on the 54th day after the outbreak of the two charts, the susceptible and recovered cases disconnected (Figure1).

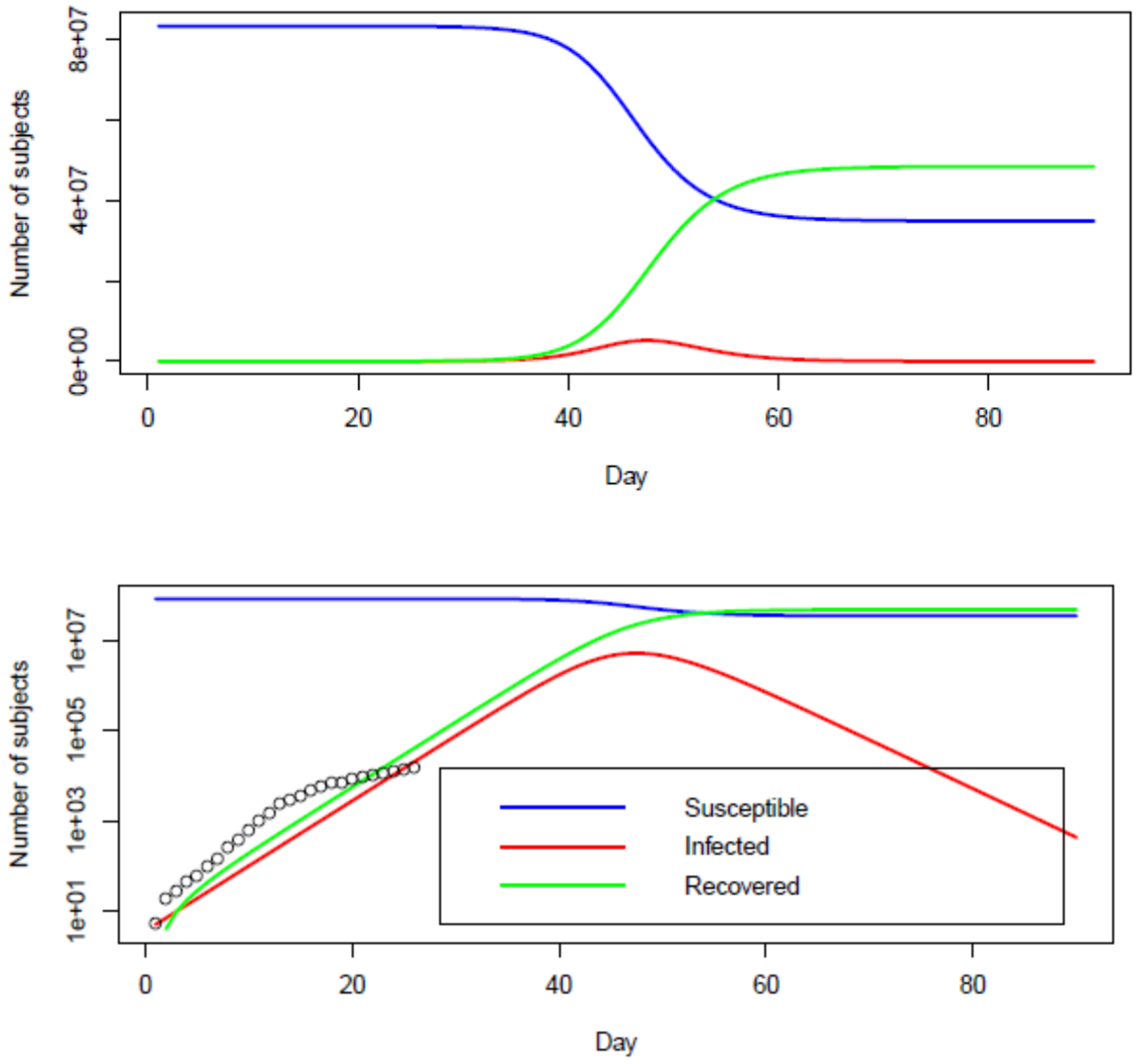

Figure1. SIR model due to 2019-nCov in Iran

Figure 1 shows us that tfinal~132 days. According to this estimate, we can expect the transmission of this epidemic to stop in Iran after July 3, 2020, provided that existing quarantine measures and patient isolation rates continue as usual. Unfortunately, there are now a large number of infected and asymptomatic people who can worse this estimate if the existing gaps are not maintained.

According to the software output, the rate of infection $\beta = 1$ and the rate of removal $\gamma = 0.667$ and index R0 = 1.497 were obtained. Because the value of R0 is more than one, it is still an epidemic disease, on the other hand, the rate of infection is constant and the rate of removal is less than one. Reducing the rate of (β) and increasing the rate of (γ) slow down the epidemic development of the disease. Therefore, effective measures to reduce the rate of infection and improve the removal rate, such as early diagnosis, early isolation and early treatment of infected cases, restricted relation, more control of infection in the hospital, and other movements to improve diagnosis and treatment of patients can slow down, control, and cut the cycle of the virus.

In comparison with the global SIR model (Figure 2), we reached the peak of the infection earlier than the global model, but in improved and susceptible cases, we performed better than the global model. The graph of recovered and

susceptible cases in Iran earlier than the global model cut off themselves.

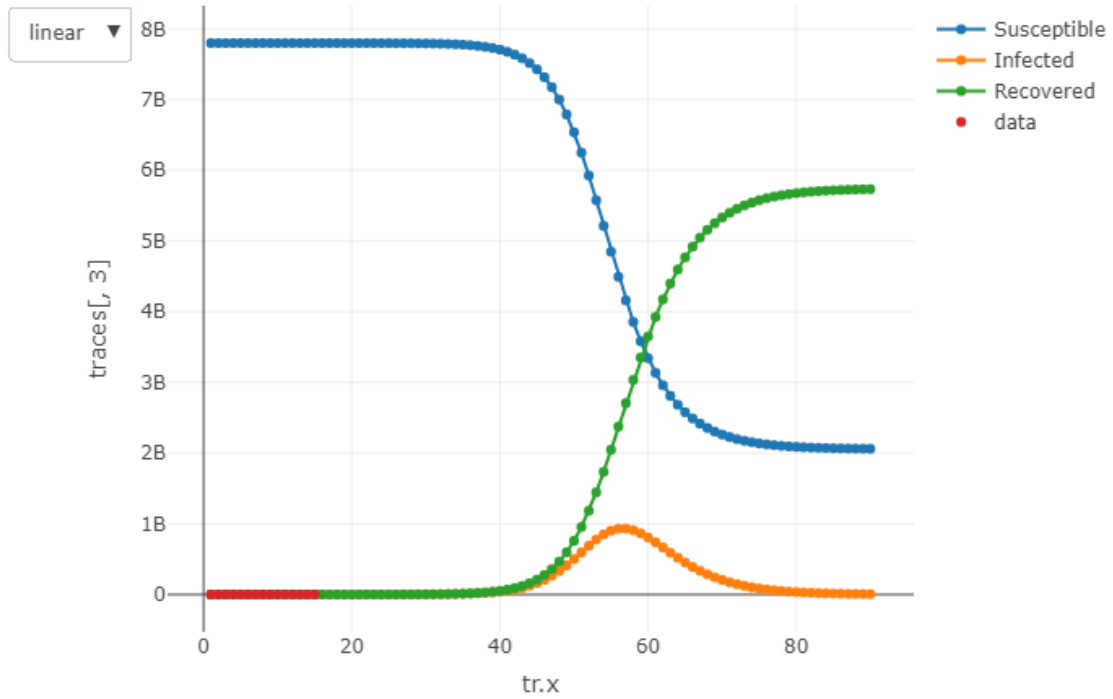

Figure2. SIR model due to 2019-nCov in World

Discussion

According to our results, the infection transmission process in Iran will stop after July 3, 2020, provided that the control measures and the rate of patient isolation continue as usual and with more rigor. Fortunately, in recovered and susceptible cases, we performed better than the global model, and given the R0 value of more than one, with more isolation and reduced virus transmission, we should try to reach R0 value less than one to completely eliminate the disease. Unfortunately, with the start of the business and a large number of asymptomatic patients, this estimate could worsen if don't control measure. The results of Nesteruk's study in South Korea show that local transmission of the pandemic disease will stop after March 20, 2020, provided that control measures and the patient's isolation continues(10).

Zhong et al in China used the simple SIR mathematical model for prediction. the model predictions exhibit that the number of the cumulative 2019-nCoV cases may reach 76,000 to 230,000, with a peak of the unrecovered infectives (22,000-74,000) occurring in late February to early March. After that, the infected cases will rapidly monotonically decrease until early May to late June, when the 2019-nCoV outbreak will fade out (3) . The results of a Tao Tang study in China showed that on the 38th day of February, the peak of coronavirus infection occurs, and the number of infectious cases in the peak of this infection will be approximately 22,000. He showed that reducing and removing the rate of infection can be effective in the progression of this epidemic (11) . Zhou Tang study in China found that when Wuhan did not take any preventive measures, assuming the average number of daily calls per infected person was k = 5, the number of infected people reached about 2384803 if applied. The restrictive rules, assuming k = 2, reduce the number of infected people to 19773 and assuming k = 1, the number of infected people decreases to 14330 and the time to reach the peak decreases by 2 days (12) .

Conclusion

Using of the SIR model in prediction and estimate novel coronavirus can be a guide and advice for the prevention and control of

epidemic disease and makes effective measures to control the epidemic in a timely manner.

Funding Support

This research resulted from an independent research without financial support.

Conflict of Interest

The authors have declared that no competing interests exist

References

1. Wu F, Zhao S, Yu B, Chen Y-M, Wang W, Song Z-G, et al. A new coronavirus associated with human respiratory disease in China. 2020;579(7798):265-9.

2. Drosten C, Günther S, Preiser W, Van Der Werf S, Brodt H-R, Becker S, et al. Identification of a novel coronavirus in patients with severe acute respiratory syndrome. 2003;348(20):1967-76.

3. Zhong L, Mu L, Li J, Wang J, Yin Z, Liu DJIA. Early Prediction of the 2019 Novel Coronavirus Outbreak in the Mainland China Based on Simple Mathematical Model. 2020;8:51761-9.

4. Kwok KO, Tang A, Wei VW, Park WH, Yeoh EK, Riley SJC, et al. Epidemic Models of Contact Tracing: Systematic Review of Transmission Studies of Severe Acute Respiratory Syndrome and Middle East Respiratory Syndrome. 2019.

5. Farnoosh GH, Alishiri GHH, Hosseini Zijoud SR, Dorostkar R, AR JF. Understanding the severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) and Coronavirus disease (COVID-19) based on available evidence -A Narrative Review Journal of Military Medicine. 2020;22(1):1-11.

6. National Health Commission's briefing on the pneumonia situation. Released on 23 Feb 2020.

7.http;//www.who.int/healthtopics/coronavirus

8.Ng TW, Turinici G, Danchin AJBID. A double epidemic model for the SARS propagation. 2003;3(1):19.

9. Kermack WO, McKendrick AG. Contributions to the mathematical theory of epidemics--I. 1927. 1991.

10. Nesteruk I. Estimations of the coronavirus epidemic dynamics in South Korea with the use of SIR model. 2020.

11. Tang T, Cao L, Lan C. SIR model for novel coronavirus-infected transmission process and its application. 2020.

12. Tang Z, Li X, Li H. Prediction of New Coronavirus Infection Based on a Modified SEIR Model. medRxiv. 2020.

13. Nesteruk I. Statistics-based predictions of coronavirus epidemic spreading in mainland China. 2020.

14. Nesteruk I. Statistics based models for the dynamics of Chernivtsi children disease. 2017(5):26-34.