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Original Article

Study and prediction of the case-fatality rate (CRF) of COVID-19 based on patient's medical information referred to Dr. Masih Daneshvari Hospital in Tehran

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Abstract

***Background & Aims*:** Coronavirus disease 2019 (COVID-19) is an acute respiratory syndrome that despite global health efforts to prevent its spread, it still has high fatality rates in many countries.

***Materials & Methods*:** Based on the medical information of 4,372 COVID-19 patients referring to Dr. Masih Daneshvari Hospital in Tehran, Iran, the case-fatality rate (CFR) for COVID-19 was calculated, and the trend of this index was assessed using the artificial neural network (ANN) model.

***Results*:** In this study, the CFR for COVID-19 reduced by an average of 0.4% per day and reached 4.43% during 50 days of the epidemic onset. Predicting the daily trend of this index using ANN model also showed a very gentle downward trend. According to the prediction of this model, during the first 100 days and also the second 100 days from the COVID-19 epidemic onset, the CFR for this disease decreased by an average of 0.03% and 0.01% per day, and reached 3.87% and 3.05%, respectively,

***Conclusion*:** The use of CFR for COVID-19 and prediction of the trend of this index for the future can provide valuable information on the diagnosis of the disease severity and evaluation of the effectiveness of control and treatment strategies, as well as assessment of the health care.

***Keywords*:** Coronavirus, Covide-19, Case-fatality rate (CFR), Artificial neural networks (ANNs), Prediction

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Introduction

Coronavirus, a family of RNA related viruses, has seven different types that could infect both humans and animals, including camels, cows, cats, and bats (1). Coronavirus could infect humans through animals or through human-to-human, as newly discovered

coronavirus that was first identified in China on December 2019. This novel coronavirus caused coronavirus disease 2019 (COVID-19) with the symptoms of severe acute respiratory syndrome (2). The COVID-19 virus spread rapidly, initially as an epidemic in China, and subsequently led to a pandemic (2). People were infected with the virus all over the world, except Antarctica (2).

Patients with COVID-19 have shown pneumonia as the most common and severe symptom and often experience dyspnea on average five days after the onset of their illness. Acute respiratory syndrome occurs in 3.4% of these patients (3, 4). Approximately 85% of patients with definite COVID-19 diagnosis had mild to moderate symptoms, and about 13% of patients suffered from severe symptoms (4, 5). In less than 6% of patients, the disease became critical and dangerous (4). Due to the growing number of new COVID-19 patients, the World Health Organization has obligated all countries to implement preventive programs and health actions (2). Despite this international attention, efforts of many countries in preventing and controlling COVID-19 were unsuccessful (6, 7). In response to the current situation, many countries introduced preventive health measure strategies to reduce the case (CFR) and infection (IFR) fatality rate (8). Estimation of CFR is another strategy that could help control the severity of infectious diseases such as COVID-19 (6, 8-10). CFR is an indicator representing the extent of disease severity, the level of public health, and health facilities, as well as predict the disease course or disease outcome. CFR could be calculated as follows:

$$\text{CFR} = \frac{\text{Number of deaths from the disease over a period of time}}{\text{Number of patients with the disease in the same period}} \times 100$$

Since the onset of the COVID-19 pandemic, CFR for this disease have been estimated in different countries of the world (6, 10, 11). Some studies have reported a CFR less than 5% for COVID -19 (7, 8, 11), while some other have reported more than 10%s (8-9). CFR calculations are important in the study of infectious diseases such as COVID-19; however, the lack of attention to the process of CFR index for a specified disease over a period of time provides limited information on disease for researchers. Therefore, studying and predicting the trend of this index for the coming days could provide the proper health planning by various strategies of the prevention and treatment to reduce disease fatality.

There are several ways to predict the CFR for COVID-19, but with the advancement of science, artificial neural networks (ANNs) have become increasingly important, compared to other methods (12, 13). ANNs is a modelling technique inspired by the human nervous system that allow to learn (13). ANNs consist of three layers, namely input layer (for receiving information), hidden layer (for taking information from the previous layers), and output layer (for keeping calculations and answering the problem). Neurons are the smallest processing unit of ANN. These neurons are interconnected in different layers of ANN (12, 13). The ANN with a hidden layer is the most widely used model. Figure 1 shows the schematic illustration of an ANN. These models could provide reasonable and predictable results in the face of missing data, heavy censoring rate, and bias (14-16). ANNs could be considered as one of the best models to study the healthcare data, as they could easily and accurately predict health indicators without the need for hypotheses or any priori identification (14, 15, 17, 18). In order to have health plan for reducing fatality of patients with COVID-19, it is very important to predict the future by measuring CFR based on an ANN-based model. Therefore, the aim of this study was to design and implement ANNs in order to predict the fatality rate of COVID-19.

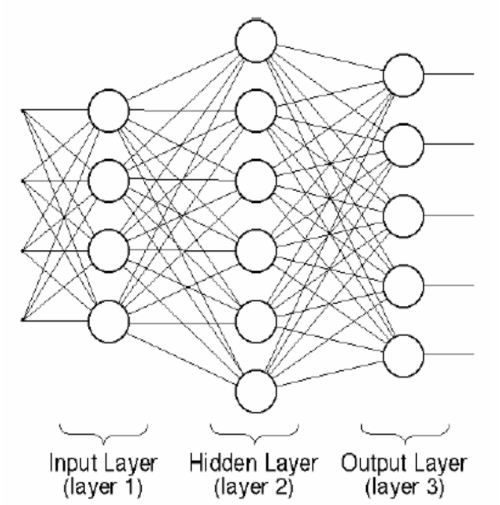

Fig. 1. Schematic illustration of an ANN with a hidden layer

Materials & Methods

To estimate the CFR for COVID-19, we studied the medical data of 4,372 patients with definite COVID-19 diagnosis referring to Dr. Masih Daneshvari Hospital (Tehran, Iran) from the beginning of February 2020 to the end of April 2020.

The ANN model was considered to predict the CFR for COVID-19. To determine the best structure of the neural network and specify the number of suitable neurons for the hidden layer, a set of ANN containing 1-25 neurons was examined. These models were compared using indicators such as the sum of squares error and relative error. Among these, ANN with one neuron for the input layer, nine neurons for the hidden layer and one neuron for the output layer with the lowest error rate were selected among other networks as the best structure of the ANN to predict the CFR for COVID-19. In this study, data analysis was performed using SPSS software version 19, as well as STATA software version 14.

Results

In the present study, the CFR for COVID-19 patients was calculated during the first 50 days from the onset of COVID-19 epidemic (Table 1). According to our results, although there were fluctuations in the CFR for COVID-19 at the epidemic onset, eventually, there was a relative decline in the CFR index and stability (about 4.5%) in the first 20-50 days of the COVID-19 epidemic. During this period, the highest and lowest values of the CFR index were about 9.83% and about 4.28 %, respectively (Table 1). The results of this study showed that the CFR of this disease has decreased by an average of 0.4% per day during the 50 days since the onset of the COVID-19 epidemic.

Table 1. Estimation of the COVID-19 CFR based on patients' medical records

Time by day from the start of the epidemic	CFR estimation of COVID- 19 based on patients' medical records	Time by day from the start of the epidemic	The CFR estimation Of COVID - 19 based on patients' medical records	Time by day from the start of the epidemic	CFR estimation of COVID - 19 based on patients' medical records
1	6.38	21	4.89	41	4.60
2	8.33	22	4.76	42	4.68
3	8.42	23	4.93	43	4.63
4	7.32	24	4.74	44	4.56
5	7.59	25	4.79	45	4.53
6	6.60	26	4.75	46	4.50
7	8.05	27	4.89	47	4.49

Time by day from the start of the epidemic	CFR estimation of COVID- 19 based on patients' medical records	Time by day from the start of the epidemic	The CFR estimation Of COVID - 19 based on patients' medical records	Time by day from the start of the epidemic	CFR estimation of COVID - 19 based on patients' medical records
8	7.38	28	4.85	48	4.48
9	9.83	29	4.75	49	4.45
10	9.55	30	4.61	50	4.43
11	7.75	31	4.49		
12	6.88	32	4.37		
13	7.41	33	4.34		
14	7.41	34	4.29		
15	7.07	35	4.30		
16	6.25	36	4.28		
17	5.88	37	4.31		
18	5.35	38	4.37		
19	5.46	39	4.59		
20	4.94	40	4.63		

Estimation of the CFR for COVID-19 by ANN model during 50 days from the onset of COVID-19 epidemic has indicated the high accuracy of this model for measuring this index. Comparison of these results, as represented in Figure 2, clearly showed that ANNs could estimate this index with high accuracy and predict its value for the coming days (Figure 2).

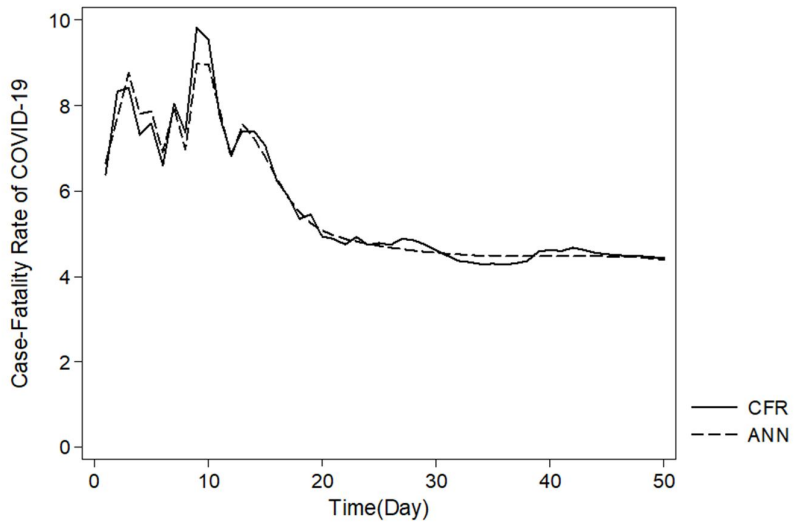

Fig. 2. Comparison of the accuracy of estimation of the CFR of COVID-19 based on the ANN model and calculation of this index using patients' medical records

Predicting the CFR for COVID-19 based on ANNs up to 200 days after the onset of the epidemic demonstrated a decreasing trend, but the slope of this trend was much milder for the first 50 days after the onset of the COVID-19 epidemic than the previous days (Figure 3). Based on the ANN model, the CFR for COVID-19 in the first 50 days of the epidemic onset was estimated to be about 4.39%, and this model predicted that from the epidemic onset to 100 and 200 days later, the index fall by about 52.5% and 1.34 %, respectively (Figure 3). In our study, the ANN model showed that during the first 100 days and the second 100 days from the onset of the epidemic of COVID-19, on average, the CFR decreased 0.03% and 0.01% per day, respectively. Also, based on the prediction of the ANN model, within 200 days from the onset of the

epidemic of COVID-19, the CFR of COVID-19 decreased by an average of 0.02% per day and reached 3.05% (Figure 3).

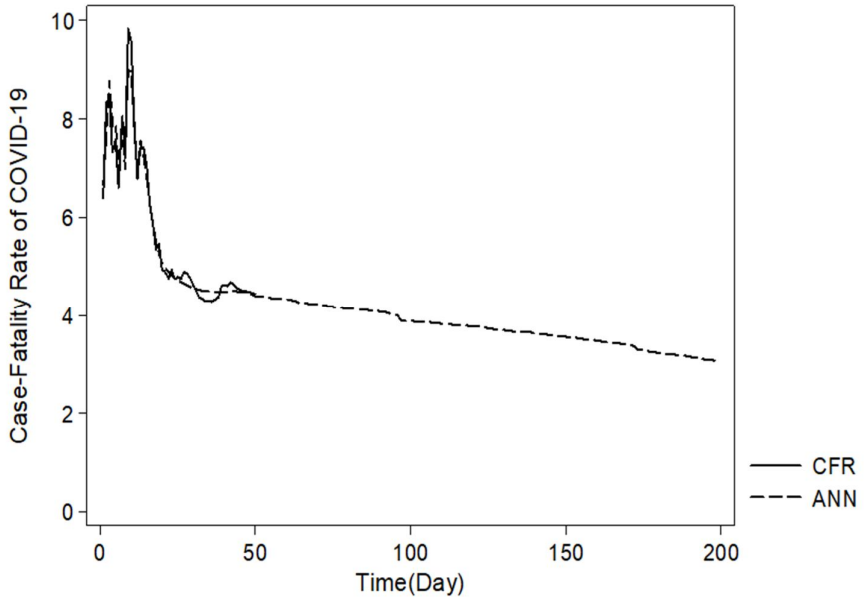

Fig. 3. Prediction of the CFR of COVID-19 according to the estimated values of this index from the patients' medical records using the ANN model

Discussion

Since the start of the pandemic of COVID-19 in China and the rapid spread of this disease in other countries, various estimations of the CFR for COVID-19 were reported (7-9, 11). In earlier studies, the CFR for COVID-19 had estimated to be less than 5% (7, 8, 11); however, some other studies have indicated a rate of more than 10% in some countries (8, 9). The CFR for COVID-19 was reported as 13.82% in France, 15.88% in Belgium, 5.5% in China, and 5.67% in the United States. This index was estimated to be 13.37% in the United Kingdom, 13.45% in Italy, 11.74% in the Netherlands, and 10.25% in Spain (6, 8-10). According to the latest statistics, the CFR for COVID-19 in Iran has been estimated as 4-6%, and this rate has been predicted to be 4.4% in Turkey (6, 9, 19, 20). There were various reasons for the variations in the CFR for COVID-19 in different countries, partly due to individual characteristics of the patients (including genetic and racial structure) and partly owing to the health and medical structures of a country (2, 6).

The main point in studying health indicators was that the most health indicators, such as the CFR at the onset of an epidemic, were severely affected and showed a high rate in the early outbreaks. Based on the results of this study, this issue could be clearly seen in the CFR estimations for COVID-19 (Table 1). In the early days of the COVID-19 outbreak, the estimated CFR for this disease was very high (about 6-9%), based on the medical information of patients with COVID-19. However, over time, from the onset of the epidemic, the CFR tended to be a constant value, which according to the results of this study was about 4.5% (Table 1). These results can be observed in Figure 2. Based on this diagram, the estimated CFR for COVID-19 both based on patient's medical information and based on the ANN model at the beginning of the outbreak of COVID-19 showed severe fluctuations. The study of the CFR for COVID-19 in the first 50

days of the epidemic exhibited that in the early days the CFR of COVID-19 was very high, and on some days, this rate has even reached nearly 10%. About 20 to 50 days after the onset of the COVID-19 epidemic, the CFR was estimated to be about 4-5% (Figure 2). The ANN model also showed good fit for data and examines changes in the CFR for COVID -19, with accuracy (Figure 2).

From the onset of the COVID-19 epidemic, ANN model predictions displayed that the CFR of the disease decreased with a very gentle slope (Figure 3). About 100 and 200 days after the start of the COVID-19 epidemic, this rate reached about 4% and 3%, respectively. Studying the CFR at a specific point of the time caused limited and ambiguous information about COVID-19 and the epidemic resulting from the spread of the disease; therefore, it was more important to study and predict the course of this indicator over time. Due to many unknown aspects of COVID-19 pandemic, no effective treatment has been established to reduce the mortality of the disease (2, 21). For this reason, in the early days of this epidemic, severe fluctuations and high mortality rates have been reported in this study, as well as in other studies (6, 8, 10). Later, a deeper understanding of the disease has emerged, and more health measures and effective therapy for the control and treatment of the disease were considered (22-25). Over the time and with effective health care measures, as well as the implementation of extensive social restrictions in countries, reduction of mortality from COVID-19 was possible, but according to the predictions of this study, the rate of this reduction was very slow, and it was impossible to reduce the CFR of this disease to zero, at least in a short time.

Conclusion

The CFR estimation in COVID-19 patients provided useful information about the disease severity and the role of health care in societies. However, predicting and studying the trend of this index over the time could play an essential role in health planning, as well as evaluating the effectiveness of treatment strategies for the control and treatment of COVID-19.

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None declared.

Conflict of interest

The authors have no conflict of interest in this study.

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Data availability

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

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