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Spatiotemporal analysis, hotspot mapping, and clustering of confirmed cases of COVID−19 in the initial phase of the pandemic in Qom province, Iran

Abolfazl Mohammadbeigi[1], Shahram Arsang−Jang[2]✉, Ehsan Sharifipour[3], Alireza Koohpaei[4], Mostafa Vahedian[5], Narges Mohammadsalehi[1], Masoud Jafaresmaeili[6], Moharam Karami[6], Siamak Mohebi[7]

[1]*Department of Epidemiology and Biostatistics, Research Center for Environmental Sciences, Faculty of Health, Qom University of Medical Sciences, Qom, Iran*

[2]*Department of Biostatistics and Epidemiology, Faculty of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran*

[3]*Neuroscience Research Center, Department of Neurology, Faculty of Medicine, Qom University of Medical Sciences, Qom, Iran*

[4]*Department of Occupational Health, Faculty of Health, Qom University of Medical Sciences, Qom, Iran*

[5]*Department of Social Medicine, Faculty of Medicine, Qom University of Medical Sciences, Qom, Iran*

[6]*Health Vic Chancellor, Qom University of Medical Sciences, Qom, Iran*

[7]*Department of Health Education, Faculty of Health, Qom University of Medical Sciences, Qom, Iran*

ABSTRACT

Objective: To identify the incidence rate, relative risk, hotspot regions and incidence trend of COVID-19 in Qom province, northwest part of Iran in the first stage of the pandemic.

Methods: The study included 1 125 officially reported PCR-confirmed cases of COVID-19 from 20 February 2020 to 20 April 2020 in 90 regions in Qom city, Iran. The Bayesian hierarchical spatial model was used to model the relative risk of COVID-19 in Qom city, and the segmented regression model was used to estimate the trend of COVID-19 incidence rate. The Poisson distribution was applied for the observed number of COVID-19, and independent Gamma prior was used for inference on log-relative risk parameters of the model.

Results: The total incidence rate of COVID-19 was estimated at 89.5 per 100 000 persons in Qom city (95% *CI*: 84.3, 95.1). According to the results of the Bayesian hierarchical spatial model and posterior probabilities, 43.33% of the regions in Qom city have relative risk greater than 1; however, only 11.11% of them were significantly greater than 1. Based on Geographic Information Systems (GIS) spatial analysis, 10 spatial clusters were detected as active and emerging hotspot areas in the south and central parts of the city. The downward trend was estimated 10 days after the reporting of the first case (February 7, 2020); however, the incidence rate was decreased by an average of 4.24% per day (95% *CI*: −10.7, −3.5).

Conclusions: Spatial clusters with high incidence rates of COVID-19 in Qom city were in the south and central regions due to the high population density. The GIS could depict the spatial hotspot clusters of COVID-19 for timely surveillance and decision-making as a way to contain the disease.

KEYWORDS: 2019 coronavirus disease; Geographic information science; Incidence rates; Spatial cluster; Spatial hotspot; Mapping

Significance

Spatial modeling is an effective approach to understand the structural and socio-demographic factors that affect COVID-19 spread in different regions. Up to today, rare studies have been designed to evaluate the spatial spread of the COVID-19 in Qom province. The results indicate that higher population density likely represents a higher risk of COVID-19.

✉To whom correspondence may be addressed. E-mail: sharsang@zums.ac.ir

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1. Introduction

The Islamic Republic of Iran reported its first 2019 novel coronavirus (COVID-19) cases on 19th February 2020 in Qom, northwest of the country[1]. Until to 4 June 2021, COVID-19 is spreaded in 220 countries and regions worldwide, and the number of confirmed cases and deaths is 179 974 279 and 3 719 003 worldwide as 2 954 309 and 80 813 in Iran, respectively[2]. As it poses a huge threat to the human community[3,4], the COVID-19 outbreak was declared a pandemic by World Health Organization on March 11th, 2020.

Spatial modeling is an effective approach to understand the structural and socio-demographic factors that affect COVID-19 spread in different regions[5]. Up to today, rare studies have been designed to evaluate the spatial spread of the COVID-19 in Qom province[1]. However, understanding the spatial spread of the COVID-19 outbreak is critical to comprehend the outbreak patterns and accordingly develop prevention policies during the early stages of the pandemic and for outbreaks down the line[3].

In this context, spatial analysis is necessary to depict the current situation of the outbreak and to prevent the spread of the disease[3,6]. Understanding the spatiotemporal patterns of the COVID-19 epidemic is critical in effectively preventing and controlling the pandemic[7,8]. Moreover, assessment of the spatial spread of the COVID-19 outbreak is also crucial to identify the dynamic of further transmission[4,6]. To this end, we used data of COVID-19 confirmed cases based on PCR results to determine the incidence rate, relative risk of the incidence, hotspot regions, and the trend of incidence in the initial phase of the pandemic in Qom city. The results of the current study may provide valuable information about the incidence of COVID-19 and the transmission of the disease, for prevention at both the individual and organization levels.

2. Materials and methods

2.1. Ethical consideration

This study was approved by the Ethical Committee of Qom University of Medical Sciences with approved No IR.MUQ.REC.1398.154 at 2020.03.10.

2.2. Study setting and subjects

Qom city located in the northerwest part of Iran, which has 90 subordinate regions. In this study, we used data of confirmed cases in the initial phase of the pandemic (from 20 February 2020 to 20 April 2020) in this city. Moreover, data of population census of the city and each region were obtained from the most recent data available. All data of confirmed cases were collected from the official database of the health Vic chancellor and its reports. Consequently, data of 1 125 cases were collected and entered into the further analysis.

2.3. Statistical analysis

Microsoft Excel 2017 (Microsoft Corporation, Redmond, WA, USA) was used to analyze data in this study. The geographical data including X and Y were received based on the residency place of cases and imported into Geographic Information System (GIS). The shapefiles of Qom city were used for ArcGIS (Environmental Systems Research Institute, Redlands, WA, USA) analysis. The segmented regression model was used to estimate the trend of the COVID-19 incidence rate. The Bayesian hierarchical spatial model implementation of the Besag, York and Mollié (BYM) model was used to model the relative risk (*RR*) of COVID-19 in Qom city. The Poisson distribution was used for the observed number of COVID-19, and independent Gamma prior for inference on log-relative risk parameters of the BYM model. The province-specific effects are assumed to follow conditional autoregressive normal prior distributions. The Bayesian posterior probability was used to test the difference of area-specific *RR* from 1. The Gelman-Rubin, trace, autocorrelation, and posterior-density plots were used to check the convergence of fitted models. The Gibbs samplers for generating samples from the posterior distribution were implemented in OpenBUGS.

3. Results

A total of 1 125 confirmed cases were included in the current study from 20 February 2020 to 20 April 2020 in 90 regions in Qom city, Iran. The mean age of the cases was (57.76±18.42) years, ranging from 1 to 98 years. The sex distribution showed that 58% (653 cases) were male and 42% (472 cases) were female. From all confirmed cases 35.8% (403 cases) died, and 64.2% (722 cases) recovered.

Figure 1 shows the estimated incidence rates for different regions in Qom city. The total incidence rate of COVID-19 was estimated at 89.6 per 100 000 persons in Qom city (95% *CI*: 84.3, 95.1). Figure 2 shows the results for *RR* of COVID-19 incidence using the BYM model. According to posterior probabilities, 43.33% (39/90) of the regions in Qom city have *RR* greater than 1, however, 11.11% (10/90) of them were significantly greater than 1. In addition, 15.55% of the regions have *RR* significantly lower than 1 (Figure 2).

Based on the results of GIS spatial analysis 10 spatial clusters was determined as active and emerging hotspot areas in the south and central of the city. The regions including Neshat (P13, *RR*=2.56), Hafte-Tir (P63, *RR*=1.977), Ammar-Yaser (P38, *RR*=1.704), Zanbilabad (P36, *RR*=1.682), Zaviyeh (P12, *RR*=1.682), Bajak-2 (P76, *RR*=1.67), Eram (P16, *RR*=1.575), Keyvanfar (P11, *RR*=1.567), 22 Bahman (P74, *RR*=1.462), and Shah-Ahmad Ghasem (P79, *RR*=1.444). All of them showed *RR* significantly greater than 1 (Figure 3). Appendix 1 shows the region's number (Pi).

The segmented regression model estimated one change point for the incidence rate trend of COVID-19 in Qom. The downward

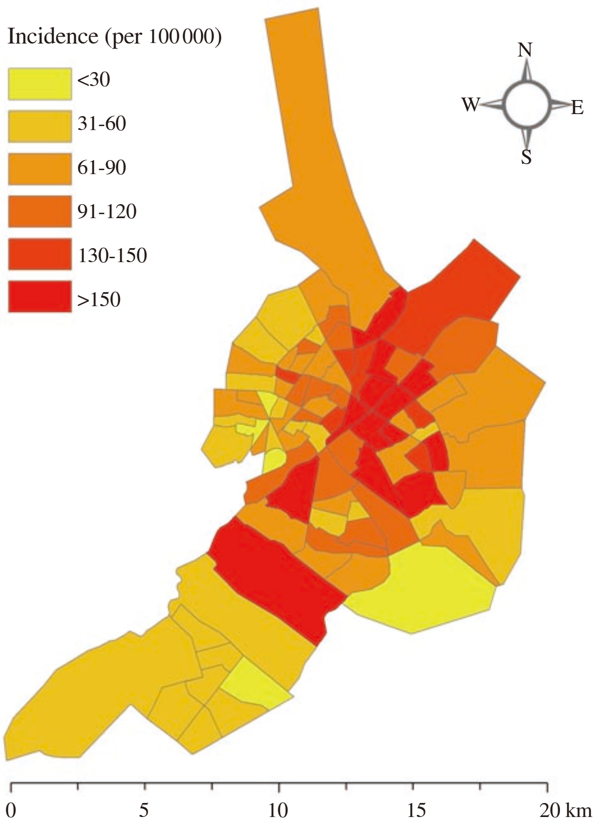

Figure 1. The estimated incidence rates of different regions in Qom city.

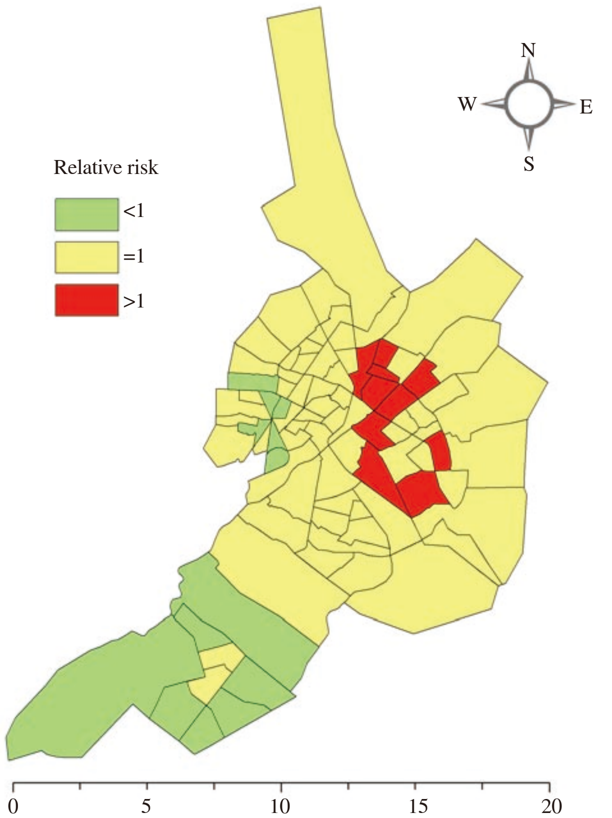

Figure 2. Bayesian hierarchical spatial model showing the relative risk of COVID-19 incidence.

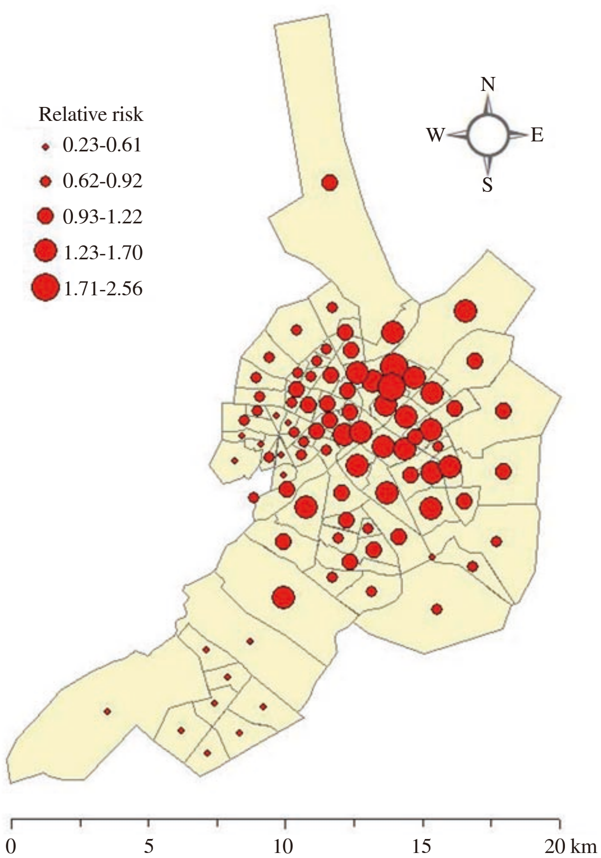

Figure 3. The hotspot regions for COVID-19 in Qom city based on the relative risk.

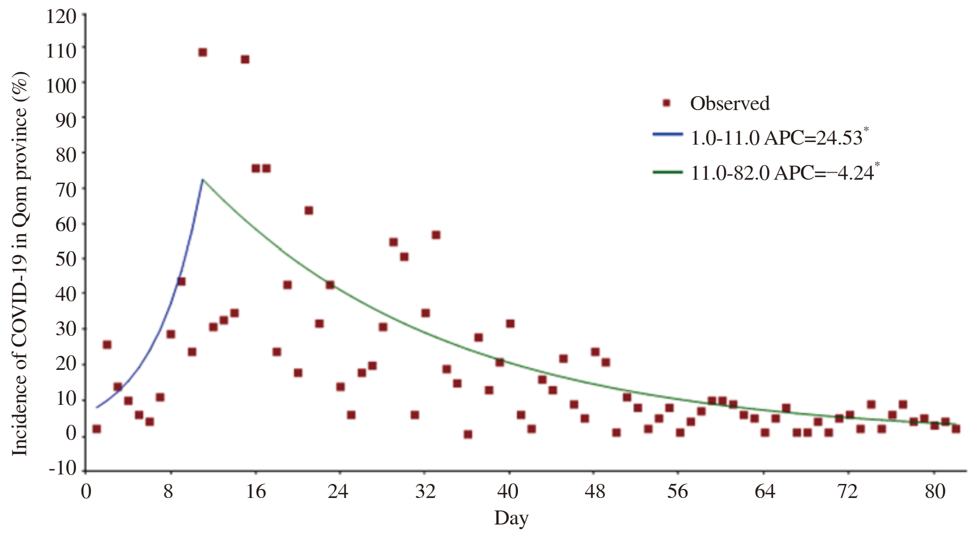

Figure 4. The incidence rate of COVID-19 trend in Qom from 20 February 2020 to 20 April 2020. APC: Annual precent change. *: The annual precent change is significantly different from zero at the alpha=0.05 level.

trend was estimated after February 7th, 2020 (10 d after the first case confirmation with COVID-19), however, the incidence rate was decreased by an average of 4.24 % per day (95% *CI*: −10.7, −3.5) (Figure 4).

4. Discussion

As a result, COVID-19 is a major threat to human health, production, life, social functioning, and international relations[5]. The total incidence rate of COVID-19 in Qom city was 89.5 per 100 000 persons and this incidence varied among different regions from 13.9 to 274.2 per 100 000 persons. Our results showed that the *RR* of COVID-19 morbidity was greater than 1 in more than 43% of regions in Qom city, while, only in 15.5% of regions, the *RR* of morbidity was lower than 1, significantly. Moreover, in 11.11% of all regions of Qom city, the risk of morbidity (*RR*) was significantly higher than 1. These results showed that the risk of COVID-19 in Qom city was high and the spread of disease in the city was expanding.

Faced with the COVID-19 pandemic, GIS could play an important role in prediction, prevention, and health policy-making[9]. Its functions include but not limited to rapid visualization of epidemic information, spatial tracking of confirmed cases, prediction of regional transmission, spatial segmentation of the epidemic risk and prevention level, balancing and management of the supply and demand of material resources, and social-emotional guidance and panic elimination[5,10].

This hotspot mapping in our study showed that the spread of COVID-19 within Qom city was spatially correlated. According the map, a cluster of regions showed significantly higher rates of COVID-19 incidence in the center of the city, which can be explained by the fact that these regions have a higher population density. More crowded and near contact to the first reffering hospital center (Kamkar Hospital) of COVID-19 in Qom beside the older population structures were the most probable factors of higher incidence of COVID-19 in this area.

According to the segmented regression model, we found that the increasing trend of COVID-19 in Qom reversed to a downward trend 10 d after the reporting of the first case, and the incidence rate was decreased approximately 4.24% per day. This is due to the slowdown dynamic of the disease and the decrease of the basic reproduction number (R0) due to effective interventions[11]. A study by Fang *et al.* showed an upward trend of R0 in the beginning and then followed by a downward trend, a temporary rebound, and another continuous decline for the COVID-19 incidence[11]. According to another study[12], rigorous government control policies were associated with a slower increase in the infected population.

Though Qom is the first city to report the COVID-19 case in Iran, some religious factors hindered the promotion and implementation of the prevention measures. Nevertheless, besides treatment, isolation and protective procedures such as social distancing and domestic quarantine were effective measures for containing the disease and decreasing R0 to lower 1. The R0 values of COVID-19 are very different among studies due to the dynamic of disease and time of the investigation. However, a review study estimated that the overall R0 estimate was 3.38±1.40, with a range of 1.90 to 6.49, higher than the data released by the World Health Organization[13]. Nevertheless, it was estimated from 2.24 to 3.58 in one study and largely followed the exponential growth[12], while it estimated 3.2 to 3.9 in another study in China[14].

Regarding the higher risk of morbidity in the central area of Qom city, we suggest that policies calling on social distancing, protecting older adults and other vulnerable populations, as well as promoting health literacy, should be developed and promoted to constrain the spread of COVID-19. Besides, Our approach could be applied to model COVID-19 outbreaks in other cities and provinces of Iran. By doing so, early detection, isolation, and treatment for suspected cases can be efficiently done as a way to control COVID-19[15].

This study was one of the first spatiotemporal analysis of COVID-19 in Iran. Therefore, it is exposed to some limitations. First the diagnosis based on PCR was limited because limitation in diagnosios kit. Second, the high incidence of diseases forced us to maping the confirmed cases to detect the hotspot areas. Due to these limitations, it is suggested for future studies one years after initial of COVID-19 pandemic.

5. Conclusions

Spatial clusters with high incidence rates of COVID-19 in Qom city were in the south and central regions due to the high population density. The GIS could depict the spatial hotspot clusters of COVID-19 for timely surveillance and decision-making as it seeks to control the disease. Therefore, increasing the early diagnosis and treatment of patients besides controlling the population migration are effective approaches to prevent and control the regional outbreak of the epidemic.

Conflict of interest statement

The authors report no conflict of interest.

Authors' contributions

Study concept and design: A.M., and S.A.; Analysis and interpretation of data: M.V., and E.S, and A.K.; Drafting of the manuscript: S.M.; Critical revision of the manuscript for important intellectual content: M.K., M.E and S,M., and E.Sh; Statistical analysis: A.M and M.V.

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