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Research Article

Estimation of Epidemiological Indicators of COVID-19 in Algeria with an SIRD Model

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Abstract

Objectives: Since the first report the coronavirus disease (COVID-19) in China on December 2019, enormous number of researches are ongoing to understand its epidemiological characteristics. One of the most important tools used to understand the epidemic curve and to predict its dynamic are epidemiological and statistical/mathematical models.

Methods: We used an SIR (Suspected-Infected-Recovered-Deceased) model to estimate the coefficients of infection, recovery and death, the reproduction number, the specific time of contact, the rate of recovery to the rate of death and the basic reproduction number and the peak of the COVID-19 epidemic in Algeria.

Results: According to the estimation of the SIRD model the peak of the epidemic will be reached on August-September in Algeria. The coefficient of infection, recovery and death are estimated at 0.1655, 0.1077 and 0.0035 (day-1) respectively. The basic reproduction value is 1.4876. The specific time of contact is estimated at 6.0423 days and the rate of recovery to the rate of death is estimated at 30.4183.

Conclusion: These results could contribute in the epidemiological characterization of COVID-19 in Algeria which will be helpful for the Algerian Authorities in the anti-COVID-19 battle. Results highlight also the role of the SIRD model in the study of COVID-19 dynamics.

Keywords: Algeria, COVID-19, SIRD model

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December, 2019 has seen the emergence of a new coronavirus disease in the city of Wuhan in the province of Hubei in China. This respiratory illness named COVID-19 has gained a global interest and was declared a pandemic of global interest by the WHO on March 11th, 2020.[1] The fast spread, the multiple clinical facets and the absence of treatment and vaccines have made of this disease a real threat to all countries through the world.[2] In this context, countries have adopted non pharmaceutical measures such as isolation and quarantine, social distancing and total or partial containment to limit the spreading of this disease. In parallel, multiple researches are ongoing to understand clinical and epidemiological characteristics of diseases.[2, 3] Understanding the transmission dynamics of COVID-19 is crucial to describe the epidemiological situations and to evaluate the effectiveness of preventive measures.[4]

One of the recognized precious tools used to understand the epidemic curve and to predict its evolution are mathematical models.[5] These models are of great importance and are used to predict the number of individuals who will be infected, determine the peak of the pandemic, the eventual second wave of the disease and the total number of

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deaths at the end of the pandemic and thus support political and health authorities to adopt the best strategies in fighting against this disease.[6]

In this way multiple mathematical model are proposed such as logistic growth models, natural growth model, Richards models, Generalized Richards models, sub-epidemics wave models and the SIR (Susceptible-Infected-Recovered) and SEIR (Susceptible-Exposed-Infectious-Removed) compartmental models and their variants which are the most common.[7, 8]

The SIR model is one of the oldest models which was used for the first time in 1927 by Kermack and McKendric.[9] Multiple derivates of these models have been later used to forecast epidemic diseases. In the current context of COVID-19, the SIR model and its derivative were largely used such as: SIQR[9] SIRD,[7, 11-13] SIRDC,[14] SIRS,[15] SRSi (Sick),[16] SIRU (unreported),[17] (eSIR),[18] MSIR,[19] SIS,[20] PIRD,[21] SEIR,[22] SEIRD,[23] SEIRDP,[24] SEIQR,[25] SEIQRD,[26] SEIQRDP,[2] SEIR-A,[27] SEAIQIm,[28] SEIARD,[29] SEIRQAD,[30] SEIHR,[31] SEQIR,[22] SEIQCRD,[33] MSEIR[19] and SIPHERD[34] models.

Algeria like other countries through the world is affected by COVID-19. It has seen its first case appear on February 25th, 2020. The number of cases increased rapidly and has reached 42.228 positive cases six months later on August 25th, 2020 (Fig. 1).[35]

During this period, the COVID-19 epidemic curve has shown multiple facets regarding daily reporting cases affected by the implemented measures and the increasing of laboratory screening capacities with a first peak in April-May and a second peak on June-July.

Figure 1 show the evolution of the number of daily cases, recovered and deaths in Algeria up to August 25th, 2020.

Despite, the fast spread of this disease in Algeria, little is known about its epidemiological parameters. Also, the number of published works about modeling and predicting the epidemic dynamics is rare.

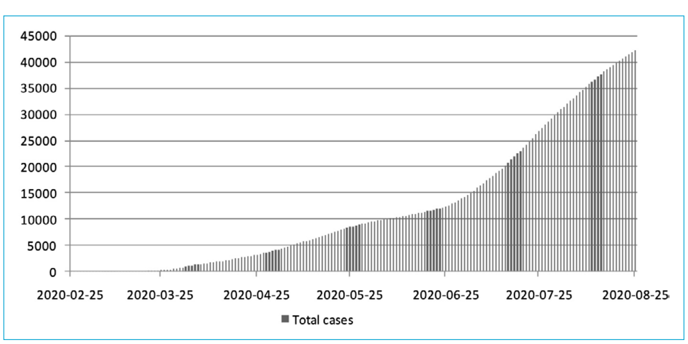

Figure 1. Evolution of the total number of COVID-19 cases in Algeria

The figure show the rapid growth of COVID-19 cases in Algeria especially since the last of June due to the lightening in preventive measures.

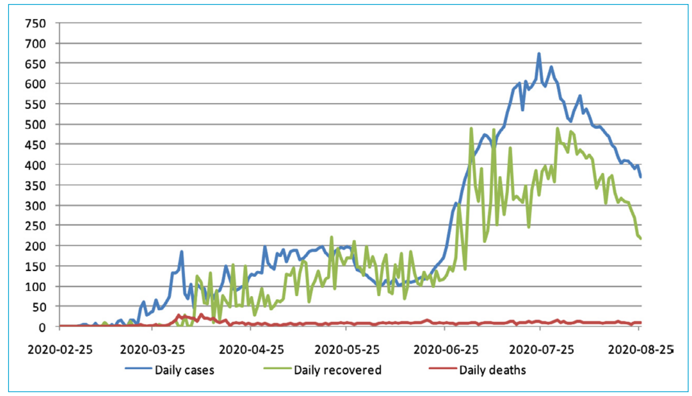

Figure 2. Daily cases, recovered and deaths reported in Algeria.

The figure show that the epidemic curve has shown two peaks: April-May and June-July, the recovered cases curve seems to be in general in a relative association with the cases curve. The death curve has shown a relative stability since the peak reported in March-April.

In this study we used a particular SIR model named SIRD model proposed by[11, 12] to characterize the epidemic curve in Algeria. To the best of our knowledge, there are no such studies using SIRD model that were carried out in Algeria.

Contrarily to the SIR model which divides the population into three compartments, in the SIRD model, the total population is separated in four categories according to their infectious status through time. These categories include the susceptible individual (S), the infected individual (I), the recovered individual (R), and the deceased individual (D) (Fig. 3) populations which are governed by a system of four differential equations.

The two first equations are non linear and are described in the normalized cases as follow:

$$\frac{ds(t)}{dt} = -\alpha_1 i(t)s(t) \quad (1)$$

$$\frac{di(t)}{dt} = \alpha_1 i(t)s(t) - \alpha_2 i(t) - \alpha_3 i(t) \quad (2)$$

The two last are linear and are described as

$$\frac{dr(t)}{dt} = \alpha_2 i(t) \quad (3)$$

$$\frac{d\delta(t)}{dt} = \alpha_3 i(t) \quad (4)$$

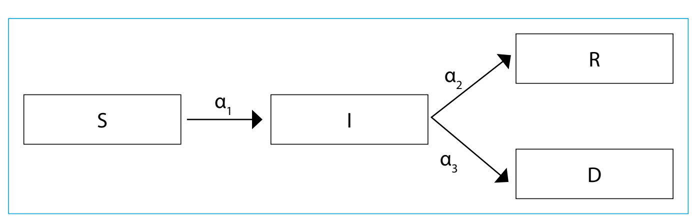

Figure 3. Scheme of the SIRD model.

Where: α_1, α_2 and α_3 define the coefficients of infection, recovery and mortality respectively. In the case of Algeria the total population N is estimated at 43.851.044 inhabitants and we assume that this number remains constant by considering an equal rate of birth and death. We assume also that the recovered persons can not be re-infected.

Note that the four equations contain the infected population (I) which represents the axial aspect of the pandemic propagation.

The following equation:

$$\frac{dr(t)}{dt} + \frac{d\delta(t)}{dt} + \frac{ds(t)}{dt} + \frac{di(t)}{dt} = 0 \quad (5)$$

Which rely the different rates (susceptible normalized population cases, infected normalized population cases, recovered normalized population cases, and deceased normalized population cases) through time represents the conservation of the total population in the system, and is considered an essential condition in solutions of the model.

Methods

To find solutions of the SIRD model for COVID-19 disease, the finite difference methods (FEMs) was used. in addition to using a part of the analytical implicit solution for the equations (3) and (4) where we can find their exact solution; we first, define the ratio as follow:

Merging and integrating equations (3) and (4) give the implicit exact form of the solutions as in.[11] Here we used the reported cases of COVID-19 in Algeria from February 25th, 2020 to August 25th, 2020 by the Algerian Health Minister to calculate the coefficients of infection (α_1), recovery (α_2) and mortality (α_3) of the SIRD model, Later, we used this parameters to calculate the number of susceptible, infected, recovered and deceased cases, the reproduction number, the specific time of contact, the estimated peak date and the ratio of the rate of recovery to the rate of mortality.

The estimation of the number of susceptible, infected, recovered and deceased individuals was done by using the finite difference of the second order formalism methods.

The basic reproduction number (R0)

To determine the basic reproduction number for COVID-19 in case of Algeria, we used the method that depends on the eigenvalues of the Jacobian of the differential equation system of the SIRD model. First, we write the Jacobian of the system and we see that the free equilibrium of the pandemic occurs at the following basic reproduction number:[12]

$$P_0 = \frac{\alpha_1}{\alpha_2 + \alpha_3} \quad (6)$$

Results and Discussion

In the current study, we used the SIRD model to estimate different epidemiological parameters of the COVID-19 pandemic basing on the reported data of cases in Algeria by the Algeria Ministry of Health.[35]

We first calculate the coefficients of infection, recovery and death. Results presented in Table 1 showed that that these coefficients are higher in Algeria than those reported in a previous study in China, the United States, Russia, the Syrian Arab Republic, France, Nigeria, Yemen and India calculated as of July 30th, 2020.[12]

Results showed also that the ratio of the recovered cases to the rate of deceased cases is estimated at 30.8143. This rate seemed to be higher than the rate calculated for India, China, the Syrian Arab Republic, France, Nigeria and Yemen but lower than the rates estimated in the United States and Russia.[12] Of note, this rate is in relation with the severity of the disease and the higher rates indicate that that the number of recovered are more important that the number of deaths. For the specific time of contact in the case of Algeria it was estimated at 6.0423 days (Table 2).

Regarding the basic reproduction number; the number of persons that could be contaminated by a diseased individual, we found that this number is estimated at 1.4876. This value is higher than the estimated values in Russia (1.2952), India (1.2561), Yemen (1.4067) and Nigeria (1.0011) but lower than those reported in France (2.7248), The USA (1.6135), and the Syrian Arab Republic (2.7936) using the same epidemic model.[12]

In addition to these results, we found the predicted dates of the actual decreasing of the new-coronavirus disease in Algeria and we estimated that the actual decreasing of the infection cases of the pandemic in Algeria is September-October of 2020 based on the same numerical simulation method. The peak seems to be later than the peak of

Table 1. The coefficient of infection, the coefficient of recovery and the coefficient of mortality of the Covid-19 pandemic for Algeria (Day^{-1})

	α_1 (d^{-1})	α_2 (d^{-1})	α_3 (d^{-1})
Algeria	0.1655	0.1077	0.0035

Table 2. The basic reproduction number, the specific time of contacts and the ratio between the recovery and the mortality rates of the new coronavirus disease for Algeria

	R_0	T_c (Days)	X
Algeria	1.4876	6.0423	30.4183

the pandemic in other countries estimated with the same model. The peak was estimated to be on July-August in Russia and on August-September for the USA, India and the Syrian Arab Republic.[12]

At last, it is to mention that these results are based on reported data based on PCR confirmed cases only and the real number of cases is higher.

Conclusion

We used the SIRD model to forecast the COVID-19 epidemic in Algeria and to estimate different epidemiological parameters. The model has allowed to estimate the coefficient of infection (α_1= 0.1655 day^{-1}), the coefficient of recovery (α_2= 0.1077 day^{-1}) and the coefficient of recovery (α_3= 0.0035 day^{-1}). The rate of the recovered cases to the rate of deceased cases was estimated at 30.8143 while the specific time of contacts was estimated at 6.0423 days. At last, the reproduction number (R_0) value of Algeria was estimated at 1.4876 and the predicted peak of COVID-19 curve will be in August-September.

This is the first study using the SIRD model to estimate epidemiological characteristics of COVID-19 in Algeria. Results of this study could contribute to understand the epidemiological characteristics of this disease in Algeria which could help deciders in adapting their preventive strategies.

Disclosures

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Conflict of Interest: None declared.

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