


COVID-19 Outbreak in Algeria: A Model to Predict Cumulative Cases

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ABSTRACT

Introduction: Since December 29, 2019 a pandemic of novel coronavirus-infected pneumonia named COVID-19 has started from Wuhan (China) and cases have been imported worldwide, in Algeria, the first case reported on February 25, 2020.

Methods: It is crucial to estimate the cases number growth in the early stages of the outbreak, to this end; we have implemented the Alg-COVID-19 Model, which allows predicting the incidence and the reproduction number R_0 in the coming months in order to help decision makers. The initial equation (1) estimates the cumulative cases at (t) prediction time using two parameters: the reproduction number (R_0) and the serial interval (SI).

Results: We found $R_0=2.55$ (95% CI 2.17–2.92) based on actual incidence of the first 26 days, using the serial interval $SI= 4.4$ and the prediction time $t=26$. The herd immunity HI estimated is $HI=61\%$. Also, The predictions fits closely the actual incidence during the first 26 days of the epidemic in Algeria which allows us to use it. According to Alg-COVID-19 Model, the number of cases will exceed 5000 on the 42nd day (April 7th) and it will double to 10000 on 46th day of the epidemic (April 11th), thus, exponential phase will begin and increases continuously until reaching a herd immunity of 61% unless serious preventive measures are considered.

Discussion: This model is valid only when the majority of the population is vulnerable to COVID-19 infection, however, it can be updated to fit the new parameters values.

Keywords: coronavirus, COVID-19, modelisation, Algeria outbreak

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INTRODUCTION

On December 29, 2019, Wuhan, the capital city of Hubei Province in Central China, has reported four cases of pneumonia with unknown etiology (unknown cause), the next day, the WHO China Country Office was informed [1] about this pneumonia cases that were found to have a link with Huanan seafood and animal market in Wuhan, the Centers for Disease Control and Prevention (CDC) and Chinese health authorities determined and announced later that a novel coronavirus denoted as Wuhan (CoV) had caused the pneumonia outbreak [2]. Since then, the outbreak has rapidly spread over a short span of time and has received considerable global attention.

On January 7, 2020 the etiological agent of the outbreak was identified as a novel coronavirus (2019-nCoV) and its gene sequence was quickly submitted [3], renamed later SARS-CoV-2 and the coronavirus disease was renamed COVID-19 by WHO on February 12, 2020. It has since been identified as a zoonotic coronavirus, similar to SARS and MERS coronaviruses [4].

On January 30, 2020, WHO announced the listing of this Novel Coronavirus-infected Pneumonia (NCP) as a “public health emergency of international concern”, a total of 254 996 confirmed cases of infection with COVID-19, including 10444 deaths have been reported worldwide as on midday March 20, 2020 [5].

Sporadic cases have been imported to Europe, Africa and North and South America via returning travellers from China. In Algeria, the first case of COVID-19 was reported on February 25, 2020, when an Italian national tested positive in Ouargla region in the south of the country, a few days later, on March 1, 2020, two cases were reported in Blida region in the North of Algeria, following their contacts with two Algerian nationals who came from France for holidays, they were detected positive after their return to France, since then, a COVID-19 outbreak has started in this region (Blida) that form a cluster of more than 5.4 million inhabitants with the surrounding cities (Algiers, Boumerdes, Tipaza) [6,7], now, the epidemic is spreading to other parts of the country, until March 22, 2020, the Algerian authorities have declared 200 confirmed cases with a case fatality rate of 8.5% (17 deaths) [6].

Meanwhile, there is considerable uncertainty as to the extent of the epidemic and its parameters, the COVID-19 reproduction number (R0) has been estimated in various studies, they found, 2,35 (95% CI 1.15–4.77) [8], two studies used stochastic methods to estimate R0 have reported a range of 2.2 to 2.68 with an average of 2.44 [9,10]. Six studies that used mathematical methods to estimate R0 produced a range from 1.5 to 6.49 with an average of 4.2 [11-15], the three studies using statistical methods such as exponential growth estimated an R0 ranging from 2.2 to 3.58, with an average of 2.67 [16,17]. Also, the COVID-19 fatality rate vary by region from 0.39% in Norway to 8,3% in Italy, in China the case fatality rate is 4% [18,19], however, the highest case fatality rate was reported in Algeria, reaching 8.5% until March 22, 2020 [6].

In the early stages of a new infectious disease outbreak, as COVID-19 in Algeria, it is crucial to estimate the transmission dynamics and inform predictions about potential future epidemic growth [20], it can provide insights into the epidemiological situation which helps decision makers to adapt the health system capacities. Thus, a prediction model can help to do that and identify whether outbreak control measures are having a measurable effect or not [21,22] and guide the design of alternative interventions [23]. In addition, a prediction model can be updated to help estimate risk to other countries [24].

To this end, we have implemented the Alg-COVID-19 Model which allows to predict the cumulative cases in the coming weeks, and to calculate the actual basic reproduction number (R0). Consequently, this model can show hospitals what to expect in terms of COVID-19 patients, amongst, the percentage of those who need to be in an intensive care unit (ICU) or on a ventilator, and also, the future number of deaths based on a given data.

METHODS

Epidemiological data

We retrieved information on cases number with confirmed COVID-19 infection based on official reports from governmental institutes in Algeria [6].

The Model Equation

This model Alg-COVID-19 only considers susceptible and infected subjects (SI model) without taking into account the recovered people, so, to predict the cumulative cases of COVID-19 Algerian epidemic in the coming weeks we used the equation defined as:

$$I(t) = p \times R0^{t/SI} \quad (1)$$

I (t): The incidence (cumulative cases number) at t time

R0: The basic reproduction number

SI: The serial interval

t: The prediction time

p: The baseline prevalence

Estimation of Basic Reproduction Number (R0) and the Herd Immunity

The basic reproduction number is defined as the (average) number of new infections generated by one infected individual during the entire infectious period in a fully susceptible population. It can be also understood as the average number of infections caused by a typical individual during the early stage of an outbreak when nearly all

individuals in the population are susceptible to infection. The basic reproduction number reflects the ability of an infection spreading under no control, it has three components [25]:

$$R0 = CB * N * D \quad (2)$$

CB: effective contact rate (C: contact frequency, B: contact efficacy)

N: susceptible population size

D: infectious phase duration

The approach implemented to estimate the basic reproduction numbers (R0) in this model is to calculate the average R0 using the actual chronological cumulative cases during the first 26 days of the COVID-19 Algeria epidemic between February 25 and March 22, 2020, so that, we used the equation (3) derived from the equation (1). The R0 will be used also to calculate the herd immunity (HI) needed to stop the epidemic spontaneously based on the equation 4.

$$R0 \text{ Average} = \left[\sum \text{Exp}^{\left(\frac{\text{Log} [I(t)/p]}{t/SI} \right)} \right] \div 26 \quad (3)$$

$$HI = \left(1 - \frac{1}{R0} \right) * 100\% \quad (4)$$

Estimation of the Serial Interval (SI)

The serial interval (SI) is the time between symptom onset of a primary and secondary case, a previous studies reported that (SI = 4.4±3.17) days [13], so we used this value in our model to predict the incidence.

Statistical Analysis and Software

This study was conducted using Excel 2013 and STATA/IC 15 software.

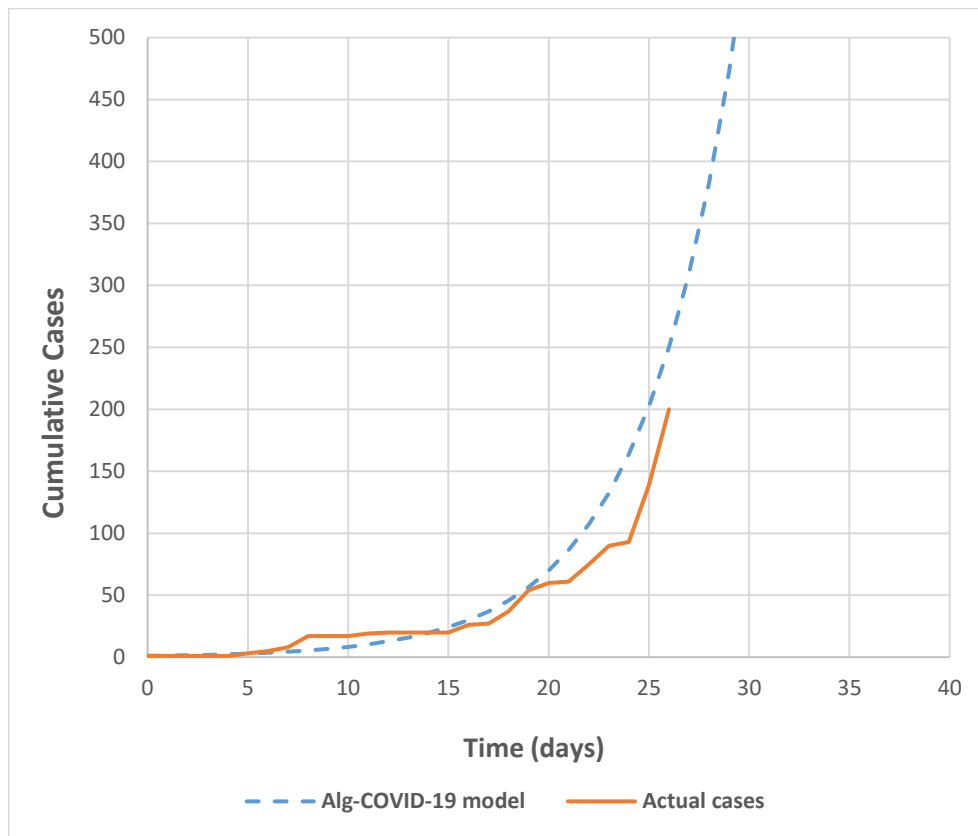
RESULTS

The Initial Parameters Used in Alg-COVID-19 Model

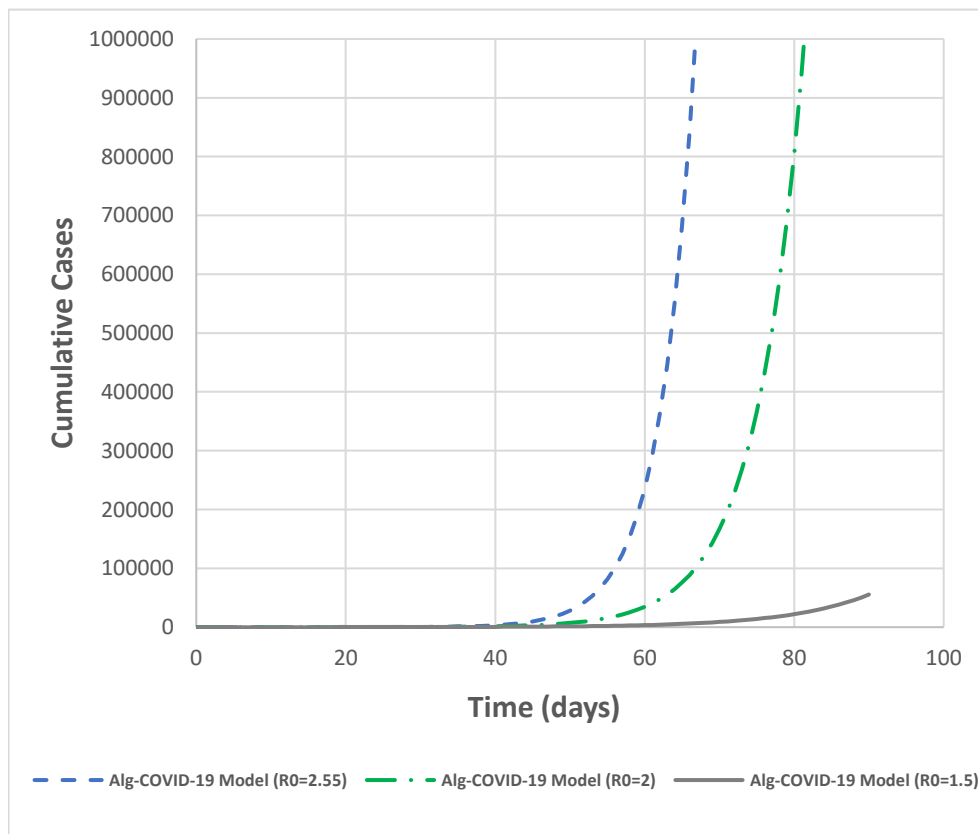
Without considering the prevention measures and other factors, this paper focused on the predicted COVID-19 incidence at any time of the epidemic using Alg-COVID-19 Model (equation 1), based on three parameter combinations that create plausible epidemic curves, namely, the average basic reproduction number calculated with the actual cases number at the first 26 days R0=2.55 (95% CI 2.17–2.92) (equation 3), the serial interval (SI=4.4) and the prediction time (t) we are looking for. The herd immunity (HI) estimated using the (equation 4) is HI=61%.

Model Fitting

The COVID-19 incidence (cases number) predicted with the Alg-COVID-19 Model fits closely the actual incidence during the first 26 days of the epidemic in Algeria (**Figure 1A**), this allows us to use this model to predict the COVID-19 incidence in the next months of the epidemic (**Figure 1B**).



A



B

Figure 1. A) Alg-COVID-19 Model match to actual data (cumulative cases) of epidemic's first 26 days. B) Alg-COVID-19 Model before mitigation ($R_0=2.55$), and after mitigation ($R_0<2.55$)

Table 1. Alg-COVID-19 Model results for next weeks without considering the preventive measures ($R_0=2.55$) and with preventive measures ($R_0=2$ and $R_0=1.5$)

Date	Days	Cases ($R_0=2,55$)	Cases ($R_0=2$)	Cases ($R_0=1,5$)
21/03/2020	25	139	139	139
22/03/2020	26	172	163	152
23/03/2020	27	213	190	167
24/03/2020	28	263	223	183
25/03/2020	29	325	261	201
26/03/2020	30	402	306	220
27/03/2020	31	497	358	242
28/03/2020	32	615	419	265
29/03/2020	33	760	490	290
30/03/2020	34	940	574	319
31/03/2020	35	1163	672	349
01/04/2020	36	1438	786	383
02/04/2020	37	1779	920	420
03/04/2020	38	2199	1077	461
04/04/2020	39	2720	1261	505
05/04/2020	40	3364	1477	554
06/04/2020	41	4160	1728	607
07/04/2020	42	5145	2023	666
08/04/2020	43	6362	2369	730
09/04/2020	44	7868	2773	800
10/04/2020	45	9730	3246	878
11/04/2020	46	12033	3799	963
12/04/2020	47	14882	4448	1055
13/04/2020	48	18404	5207	1157
14/04/2020	49	22759	6095	1269
15/04/2020	50	28146	7135	1393
16/04/2020	51	34807	8353	1526
17/04/2020	52	43045	9778	1673
18/04/2020	53	53233	11446	1835
19/04/2020	54	65832	13399	2012
20/04/2020	55	81413	15685	2206
21/04/2020	56	100681	18361	2419
22/04/2020	57	124510	21494	2653
23/04/2020	58	153979	25162	2909
24/04/2020	59	190423	29455	3189
25/04/2020	60	235491	34480	3497
26/04/2020	61	291227	40363	3835
27/04/2020	62	360153	47250	4205
28/04/2020	63	445392	55312	4611
29/04/2020	64	550806	64749	5056
30/04/2020	65	681169	75797	5544

Alg-COVID-19 Model Results

The estimations presented by this model are based on the first 26 days data and cover the next months of COVID-19 epidemic in Algeria, according to that, the number of cases will exceed 1000 cases on the 35th day of the epidemic (March 31, 2020), 5000 on the 42nd day (April 7th) and it will double to 10000 on 46th day of the epidemic (April 11th), thus, exponential phase will increase continuously until reaching a herd immunity of 61% or a serious preventive measures are considered (Table 1; Figure 1B).

DISCUSSION

Regarding the used parameters (R_0 and SI) by Alg-COVID-19 Model for the predictions, the estimated $R_0=2.55$ (95% CI 2.17–2.92) until March 19, 2020, is very close to R_0 that was found on the Chinese epidemic data $R_0=2,35$ (95% CI, 1.15–4.77) until February 4th, 2020 [8], also, it is in the range of basic reproduction numbers of other studies mentioned below [11–15], on the other hand, the parameter that we cannot update and can affect the predictions is the serial interval (SI), we found two studies each one has different value that range from

4.4±3.17 [13] to 7.5 days (95% CI, 5.3-19) [26], we used (SI=4.4) because of its standard deviation is not very large.

This model only considers susceptible and infected subjects (SI model) without taking into account the recovered people, so, it is valid only when the majority of the population is vulnerable to COVID-19 infection, without taking into consideration the herd immunity acquired by recovered people ongoing epidemic and the ability of getting infected a second time.

In case of R_0 decreases over the next weeks of the epidemic, Alg-COVID-19 Model can be revalidated by recalculating a new effective reproductive number R_1 (equation 3). However, this will happen only if the herd immunity rises spontaneously during the epidemic or if serious preventive measures acting directly on one of the components of R_0 will be taken (equation 2).

In the case of the Algerian COVID-19 epidemic, this model can be valid for the first few months if the herd immunity remains low and susceptible population size c change, thus, it is applicable whenever a new regional outbreak begins with a naive population. On the other hand, if the state implements a good preventive policy according to the WHO guidelines [5] and set up measures to reduce the effective contact rate, this will obviously reduce R_0 , so that, (R_1) the effective reproduction number with control and preventive measures can be calculated to estimate the implemented preventive actions effectiveness and performance. The Alg-COVID-19 Model can be updated with R_1 values adapted to the new situation and its forecasts would correspond as closely as possible to the real epidemic growth (Figure 1B). Furthermore, it is obvious that the measures must be strong enough to reduce the basic reproduction number below 1 ($R_0 < 1$) to control the epidemic, otherwise, it will spread over time, which can also be a good strategy for maintaining the healthcare demand at a manageable pace.

According to Alg-COVID-19 Model results based on Algerian data without taking into account the preventive measures ($R_0=2.55$), the exponential phase will begin after the 35th day of the epidemic (1000 cases) by March 31, 2020, consequently, the response to the epidemic will change from trying to curb the spread of the COVID-19 on the territory to a strategy that lead to mitigate the effects of the epidemic waves, so that, after R_0 and SI update (Figure 1B), the model can be used to predict the number of; hospitalization, ICU or under ventilator patients, and also, to predict the number of deaths that remains the highest in the world (Algeria: 8.5% until March 22nd) since the start of the pandemic, without any concrete explanation. Predictions with preventive measures at $R_0 = 2$ and $R_0 = 1.5$ are also presented in Table 1.

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