COVID-19 outbreak in Algeria: A mathematical Model to predict cumulative cases

Abstract

Introduction: Since December 29, 2019 a pandemic of new novel coronavirus-infected pneumonia named COVID-19 has started from Wuhan, China, has led to 254 996 confirmed cases until midday March 20, 2020. Sporadic cases have been imported worldwide, in Algeria, the first case reported on February 25, 2020 was imported from Italy, and then the epidemic has spread to other parts of the country very quickly with 139 confirmed cases until March 21, 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 to predict the incidence and the reproduction number R0 in the coming months in order to help decision makers.

The Alg-COVIS-19 Model initial equation 1, estimates the cumulative cases at t prediction time using two parameters: the reproduction number R0 and the serial interval SI.

Results: We found R0=2.55 based on actual incidence at the first 25 days, using the serial interval SI= 4,4 and the prediction time t=26. The herd immunity HI estimated is HI=61%. Also, The Covid-19 incidence predicted with the Alg-COVID-19 Model fits closely the actual incidence during the first 26 days of the epidemic in Algeria Fig. 1.A. which allows us to use it.

According to Alg-COVID-19 Model, the number of cases will exceed 5000 on the 42th day (April 7th) and it will double to 10000 on 46th day of the epidemic (April 11th), thus, exponential phase will begin (Table 1; Fig.1.B) and increases continuously until reaching à 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, A mathematical model, Algeria outbreak.

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 (WHO.a 2020) 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 (CDC 2020). 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 (GenBank 2019), the coronavirus 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. (Ying, et al. 2020)

On January 30, 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 20th, 2020 (WHO.a 2020).

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) (Algerian Ministry of Health 2020, ONSA 2020), 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 fatality rate of 8,5% (17 deaths) (Algerian Ministry of Health 2020).

Meanwhile, there is considerable uncertainty as to the extent of the epidemic and its parameters, the COVOD-19 reproduction number (R0) has been estimated in various studies, they found, 2,35 (95% CI 1.15–4.77) (Kucharski, et al. 2020), two studies used stochastic methods to estimate R0 have reported a range of 2.2 to 2.68 with an average of 2.44. (Joseph, et al. 2020, Riou et Althaus 2020), Six studies that used mathematical methods to estimate R0 produced a range from 1.5 to 6.49 with an average of 4.2. (Shen, et al. 2020, Read, et al. 2020, Chong, et al. 2020, Natsuko, et al. 2020, Tang, et al. 2020) 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. (Liu, et al. 2020, Zhao, et al. 2020). Also, the COVID-19 fatality rate vary by region from 0.39% in Norway to 8,3% in Italy, in China the fatality rate is 4%, (Wilson, et al. 2020, Johns Hopkins 2020), however, the highest mortality rate remain in Algeria at 8,5% until March 22, 2020 (Algerian Ministry of Health 2020)

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 (Viboud, et al. 2018), it can provide insights into the epidemiological situation which help 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 (Funk, et al. 2017, Riley, et al. 2003) and guide the design of alternative interventions (Kucharski, et al. 2015), in addition, a prediction Model can be updated to help estimate risk to other countries (Cooper, et al. 2006).

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, the percentage who need to be in an intensive care unit (ICU) or on a ventilator and 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 (Algerian Ministry of Health 2020).

The mathematical Model

In order to predict the cumulative cases of COVID-19 Algerian epidemic in the coming weeks we used the mathematical model (Alg-COVID-19) defined as:

$$\boldsymbol{I}(\boldsymbol{t}) = \boldsymbol{R0}^{\boldsymbol{t/SI}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

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

R0: The reproduction number

SI: The serial interval

t: The prediction time

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 (Roy, et al. 1992):

R0= CB*N*D…………(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.

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

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

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 (Chong, et al. 2020), 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 2.15–2.93) (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 (Fig. 1.A), this allows us to use this Model to predict the Covid-19 incidence in the next months of the epidemic (Fig. 2.B).

Alg-COVIS-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 case on the 35^{th} day of the epidemic (March 31, 2020), 5000 on the 42^{th} day (April 7^{th}) and it will double to 10000 on 46th day of the epidemic (April 11^{th}), thus, exponential phase will increases continuously until reaching à herd immunity of 61% or a serious preventive measures are considered (Table 1; Fig.1.B).

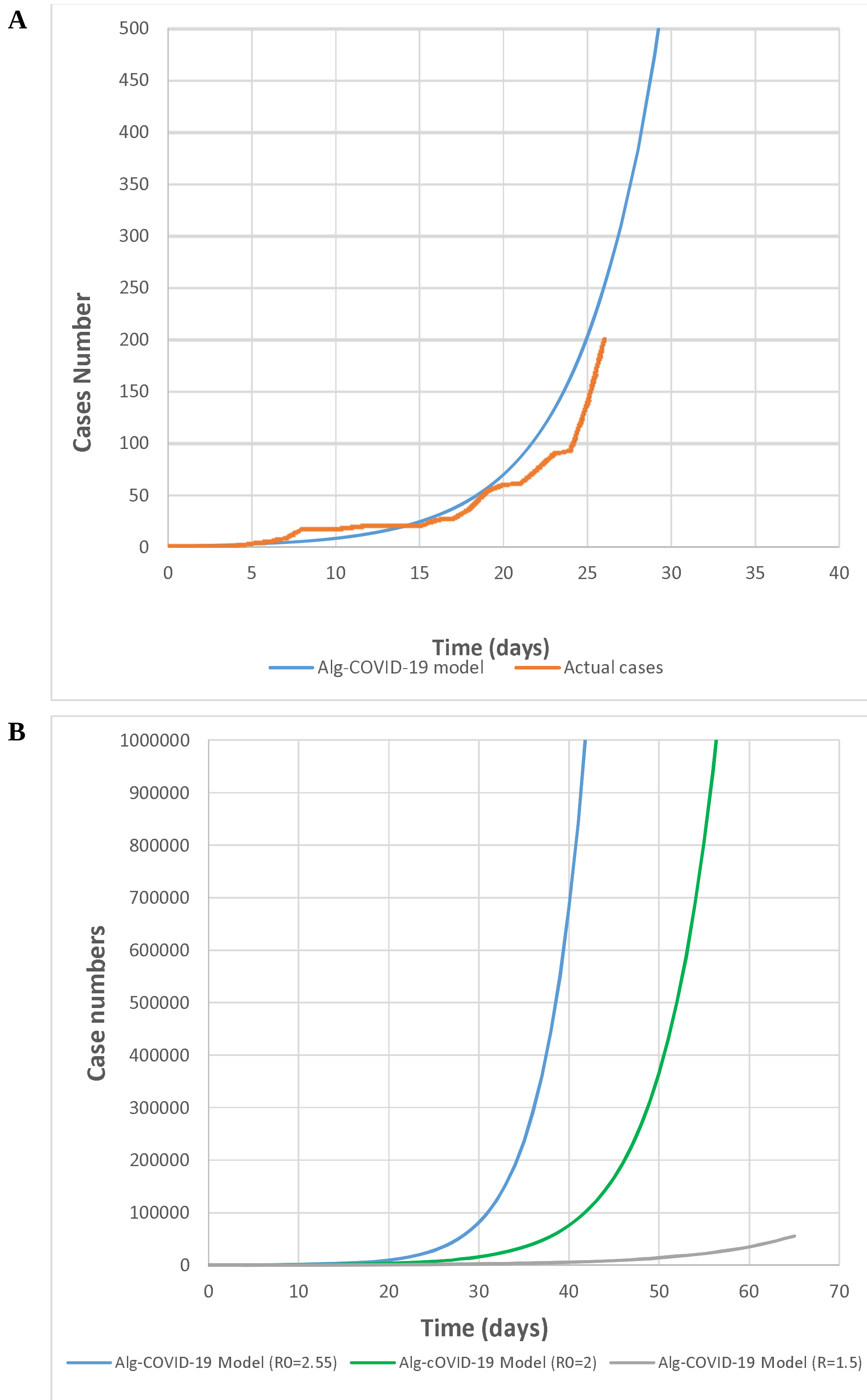

Fig. 1. A: Alg-COVID-19 Model match to actual data (Cases number) of the first 26 days of epidemic. B: Alg-COVID-19 Model before and before (R0=2.55) and after mitigation (R0<2.55).

Table 1. Alg-COVID-19 Model results for next weeks

Date	Days	Cases	Date	Days	Cases	Date	Days	Cases
21/03/2020	25	139	12/04/2020	47	14881,5074	04/05/2020	69	1593232,1
22/03/2020	26	171,897993	13/04/2020	48	18403,6061	05/05/2020	70	1970312,24
23/03/2020	27	212,582158	14/04/2020	49	22759,3019	06/05/2020	71	2436638,26
24/03/2020	28	262,895297	15/04/2020	50	28145,8871	07/05/2020	72	3013332,57
25/03/2020	29	325,116359	16/04/2020	51	34807,3489	08/05/2020	73	3726516,7
26/03/2020	30	402,063666	17/04/2020	52	43045,4203	09/05/2020	74	4608494,54
27/03/2020	31	497,22257	18/04/2020	53	53233,2472	10/05/2020	75	5699215,55
28/03/2020	32	614,903323	19/04/2020	54	65832,2902	11/05/2020	76	7048084,27
29/03/2020	33	760,436309	20/04/2020	55	81413,2271	12/05/2020	77	8716198,13
30/03/2020	34	940,413492	21/04/2020	56	100681,801	13/05/2020	78	10779114,9
31/03/2020	35	1162,98699	22/04/2020	57	124510,788	14/05/2020	79	13330274,9
01/04/2020	36	1438,23834	23/04/2020	58	153979,529	15/05/2020	80	16485233,8
02/04/2020	37	1778,63514	24/04/2020	59	190422,82	16/05/2020	81	20386896,4
03/04/2020	38	2199,59576	25/04/2020	60	235491,371	17/05/2020	82	25211989,8
04/04/2020	39	2720,18774	26/04/2020	61	291226,576	18/05/2020	83	31179067,9
05/04/2020	40	3363,99146	27/04/2020	62	360152,977	19/05/2020	84	38558411,5
06/04/2020	41	4160,16821	28/04/2020	63	445392,618	20/05/2020	85	47684270,1
07/04/2020	42	5144,78104	29/04/2020	64	550806,454	21/05/2020	86	58970002,3
08/04/2020	43	6362,42831	30/04/2020	65	681169,237	22/05/2020	87	72926798,8
09/04/2020	44	7868,26372	01/05/2020	66	842385,789	23/05/2020	88	90186837,1
10/04/2020	45	9730,49454	02/05/2020	67	1041758,46	24/05/2020	89	111531916
11/04/2020	46	12033,4711	03/05/2020	68	1288317,91	25/05/2020	90	137928867

Discussion

Regarding the used parameters (R0 and SI) by Alg-CIVID-19 Model for the predictions, the estimated R0=2.55 (95% CI 2.15–2.93) until March 19, 2020, is very close to R0 that was found on the Chinese epidemic data R0=2,35 (95% CI 1·15–4·77) until February 4th , 2020, (Kucharski, et al. 2020), also, it is in the range of basic reproduction numbers of other studies mentioned below (Shen, et al. 2020, Read, et al. 2020, Chong, et al. 2020, Natsuko, et al. 2020, Tang, et al. 2020), 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 (Chong, et al. 2020) to 7.5 days (95% CI, 5.3 to 19) (Li, et al. 2020), we used (SI=4.4) because of its standard deviation is not very large.

This model is valid only when the majority of the population is vulnerable to COVID-19 infection, since it does not take into account the herd immunity acquired ongoing epidemic.

In case of R0 decreases over the next weeks of the epidemic, Alg-COVID-19 Model can be revalidated by recalculating a new effective reproductive number R1 (equation 3). However, this will happen only if the herd immunity rises spontaneously during the epidemic or the state act on one of the components of R0 by preventive measures (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 remain low and susceptible population size is not changed, thus, it is applicable whenever a new regional outbreak begins with a naive population. On the other hand, if the state implement a good preventive policy according to the WHO guidelines (WHO.b 2020) and set up measures to reduce the effective contact rate, this will obviously reduce R0, so that, (R1) the effective reproduction number with control and preventive measures can be calculated to estimate the implemented preventive actions effectiveness, and Alg-COVID-19 Model can be updated with R1 values adapted to the new situation and its forecasts would correspond as closely as possible to the real epidemic growth (Fig.1.B). Also, it is obvious that the measures must be strong enough to reduce the basic reproduction number below 1 (R0 <1) to control the epidemic, otherwise, the epidemic 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 on Algeria data, the exponential phase 3 will probably announced after the 35^{th} day of the epidemic (1000 case) (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 wave, so that, after R0 and SI update (Fig. 1.B), the Model can be used to predict the hospitalization and ICU or on a under ventilator patients numbers, and also, predict the number of deaths that remain the highest in the wold (Algeria: 8.5% until March 22^{nd}) since the start of the pandemic, without any concrete explanation.

Conflict of Interest Statement

The authors have no conflicts of interest to declare

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