Original Article

Situational Analysis and Epidemic Modeling of COVID-19 in Egypt

Ali A. Hasab [1][¥], Engy M. El-Ghitany [2], Nermeen N. Ahmed [1]

[1] Department of Epidemiology, High Institute of Public Health, Alexandria University, Egypt

[2] Department of Tropical Health, High Institute of Public Health, Alexandria University, Egypt

Abstract

Background: Since its emergence in December 2019, the COVID-19 virus has spread to every continent on earth. Countries are racing to slow down the spread of the disease. The pandemic is still ongoing and global efforts are marathoning to comprehend the virus biology, epidemiology, natural history and eventually applying the sound control measures promptly.
Objectives: The study was carried out to demonstrate the epidemiological distribution and modeling of the novel Coronavirus (COVID-19) epidemic in Egypt.
Methods: Secondary data in the situation reports of WHO, Worldometer and Egyptian MoHP Report about the COVID-19 epidemic in Egypt were analysed till April 10, 2020. Wolfram Player 12 software was used for the Susceptible Infected Recovered (SIR) epidemic dynamics of COVID-19 pandemic.
Results: The cumulative proportional survival at the end of the epidemic is expected to be 82%. Meanwhile, the transmission rate per infectious individual (β) was 0.09 and the recovery rate (γ) was 0.30. The fraction of infectious individuals is not expected to grow exponentially. The basic reproductive rate ($R0$) was 0.23 and the duration of infection was 2.62 days
Conclusion and recommendation: As for the available data by April 10th, 2020, Egypt COVID-19 epidemic situation is not frightening. Even though, strengthening all the mitigation efforts to keep the exposure probability, as well as the transmission rate as low as possible is mandatory for containment of the epidemic.

Keywords: COVID-19, Egypt, Epidemic SIR model, Pandemic

INTRODUCTION

The Coronavirus pandemic is the defining global health crisis of our time. Since its emergence in late 2019, the virus has spread to every continent. Countries are racing to slow the spread of the disease by testing and treating patients, carrying out contact tracing, limiting travel, quarantining citizens, and cancelling large gatherings such as sporting events, concerts, and schools. The pandemic is moving like a wave—one that may yet crash on those least able to cope.[1] But COVID-19 is much more than a health crisis. By stressing every one of the countries it touches, it has the potential to create devastating social, economic and political crises that will leave deep scars. Dozens of the world's greatest cities are deserted as people stay indoors, either by choice or by government order. Across the world, shops, theatres, restaurants and bars are closing.[2, 3] Every day, people are losing jobs and income, with no way of knowing when normality will return. The International Labor Organization[4] estimates that 25 million jobs could be lost.[5]

The situational analysis of COVID -19 pandemic and prospects in Egypt is appreciated by the researchers. The results of which can be translated into sound policy and decision making. Therefore, this study was conducted to discuss the epidemiological distribution and modeling of the novel COVID-19 epidemic in Egypt and explain the relationship between the populations that are infectious, susceptible and recovered.

METHODS

The data was collected essentially by using secondary data. All cases and deaths in the situation reports of WHO[3] and the Worldometer till 10th of April 2020 were included in the study.[6] Every case was represented by a row. Death was coded as 1 and cases

by 0. Egyptian Ministry of Health & Population (MoHP) report issued on the 2nd of April, 2020, was also included.[7] The data were entered and analyzed by IBM SPSS Statistics, 25th edition[8] and SAS University 4th Edition.[9] Survival analysis was carried out to determine the case fatality rate (CFR), where new cases were added, while deaths and recovered cases were subtracted. The death rate among COVID-19 cases with defined outcome was calculated as the number of deaths divided by the total number of cases with defined outcome (either died or cured). Wolfram Player 12 software was used for the Susceptible Infected Recovered (SIR) epidemic dynamics of COVID-19.[10]

The following SIR model was considered: where S is the fraction of susceptible individuals, I is the fraction of infectious individuals, and R is the fraction of recovered individuals, β is the transmission rate per infectious individual, and γ is the recovery rate. So in the SIR model, members of a population are categorized into one of three groups: those who are susceptible to being infected, those who have been infected and are able to spread the disease to susceptible individuals, and those who have recovered from the disease. Movement of individuals is one-way only, S - I – R.

RESULTS

The total number of cases of COVID–19 in the world on 10th April was 1,678,905 with 101,680 deaths. In Egypt, the total number of reported cases was 1,794, and 135 deaths. Figure (1) shows the distribution of COVID-19 cases. In addition, the total number of recovered cases was 384 cases, while active cases were 1,275. The survival analysis results showed that the cumulative proportional survival at the end of the interval was 0.82; translated into a CFR of 18%. This means that 82% of the active cases of COVID-19 at 10th April, 2020, in Egypt are expected to survive by the end of the epidemic (Table 1).
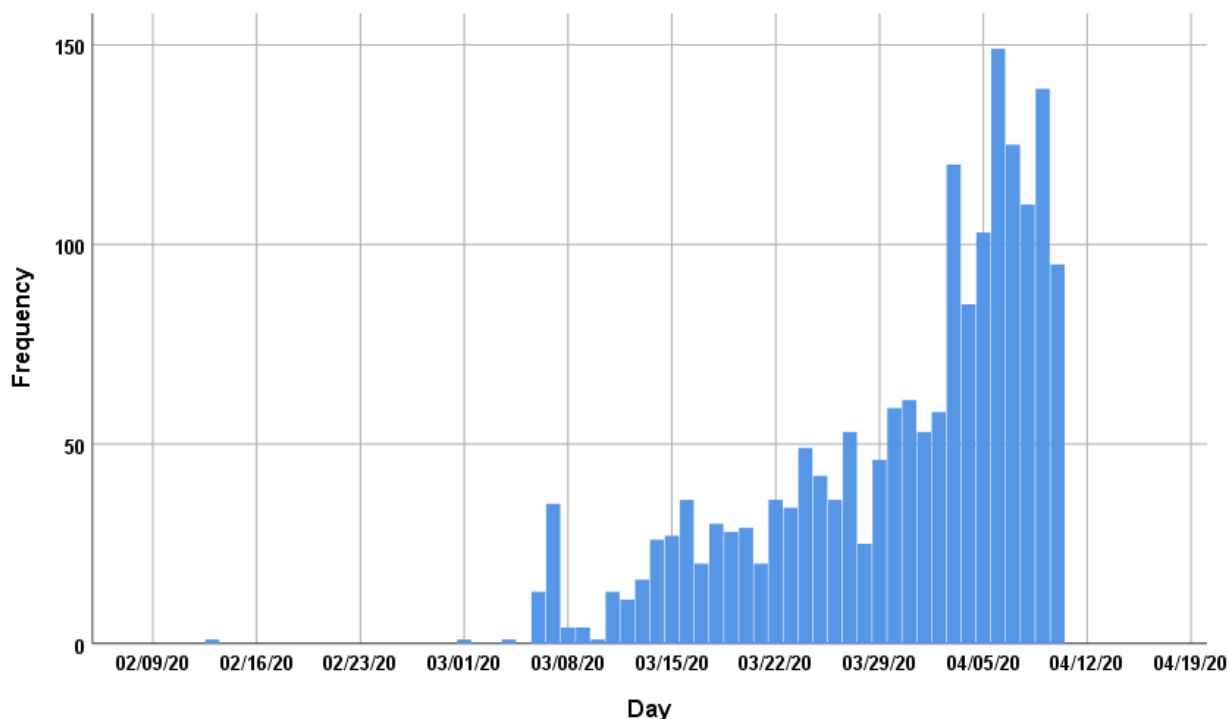

Figure 1: Distribution of the COVID-19 cases in Egypt (9th February-10th April 2020)

Table 1: Life table of proportion surviving of COVID-19 cases in Egypt (10th February -10th April 2020)

Interval Start Time	Number Entering Interval	Number of Terminal Events	Proportion Terminating	Proportion Surviving
0	1327	0	.00	1.00
1	1327	135	.18	0.82

Reanalysis of the Egyptian MoHP report

Reanalysis of the 2nd April Egyptian MoHP report showed that the total number of cases reported in Egypt was 868 cases (61.3% males and 38.7% females) with 59 deaths and 154 recovered. The mean age was 45.4 years. The death rate among COVID-19 cases with defined outcome was calculated as the number of deaths divided by the total number of cases discharged (either died or cured). In Egypt It was 27.7 %; 28.79% among males and 25.93% among females with no significant difference (Table 2).

Table (3) showed that COVID-19 cases of 60 years and above age had more than seven odds of the disease than those below 60 years with a significant difference (cOR (95% CI)= 7.179 (3.744 -14.0167), χ^2 MH= 37.416, *p*= 0.000). The report also shows that out of the admitted cases, only 18 (2.0%) need intensive care unit (ICU) admission and healthcare. The majority of the admitted cases were Egyptians, while only 7% were foreigners. The bed occupancy rate in the quarantine centers in Egypt ranged from 11% to 89%, with a mean of 53%.

Table 2: Distribution of the discharged cases of COVID- 19 by sex and outcome, 2nd April 2020

Sex		Discharged		Total	Chi-Square (*p*)
		Death	Recovered		
Male	No.	38	94	132	
	%	28.79	71.21	100.0	
Female	No.	21	60	81	0.205 (*p*= 0.65)
	%	25.93	74.07	100.0	
Total	No.	59	154	213	
	%	27.7	72.3	100.0	

Table 3: Distribution of the discharged cases of COVID- 19 by age and outcome, 2nd April 2020

Age group (years)		Discharged		Total
		Death	Recovered	
60 and above	No.	35	26	61
	%	57.38	42.68	100.0%
Below 60	No.	24	128	152
	%	15.79	84.21	100.0%
Total	No.	59	154	213
	%	27.7	72.3	100.0%

cOR = 7.179 (3.744 -14.0167)
χ^2 MH = 37.416, P= 0.000

Epidemiological Modelling of COVID-19 epidemic in Egypt

In Egypt on 10th of April 2020, the number of reported cases was 95 and that of the recovered was 29. β was calculated by the equation: C= βSI – Iγ
124= β x 102332404x95- 95 x.3
β was 0.09 and γ= 0.30.
Where C is the incidence of cases in the second day, S is the susceptible population, I is the number of cases in 10th April and γ is the recovery rate. The recovery rate was calculated by dividing the recovered cases by the reported cases, 29/95 = 0.3. Note that the basic reproduction number (R0) is R =β/γ, the basic reproductive rate= 0.23 (Less than one person

infected). The infectious period is exponentially distributed with a mean 1/γ and the duration of infection was 2.62 days. Consider the SIR model in a disease free equilibrium, representing a completely susceptible population. As the transmission rate – recovery rate < 0, the fraction of infectious individuals is not expected to grow exponentially and the incidence rate (number of new cases per unit time) also will not increase exponentially. In Egypt on 10th of April 2020 β was 0.09 and γ= 0.30. The fraction of infectious individuals will not grow exponentially in Egypt. The exponential growth rate is λ=β−γ. Figure 2 illustrates the different SIR models in Egypt, the USA and all over the world.

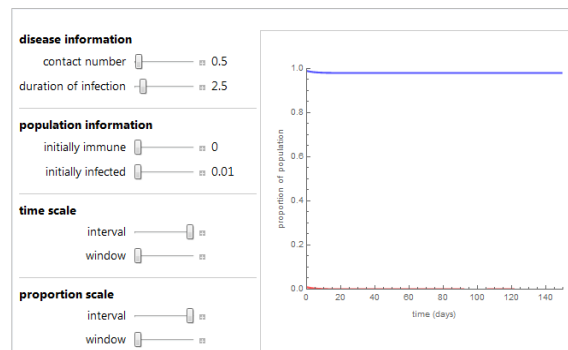**Figure 2 (A, B &C) The SIR Epidemic Dynamics of COVID-19 in Egypt, the world and the USA**

Figure (2A): SIR Epidemic Dynamics of COVID-19 in Egypt, 10th April 2020

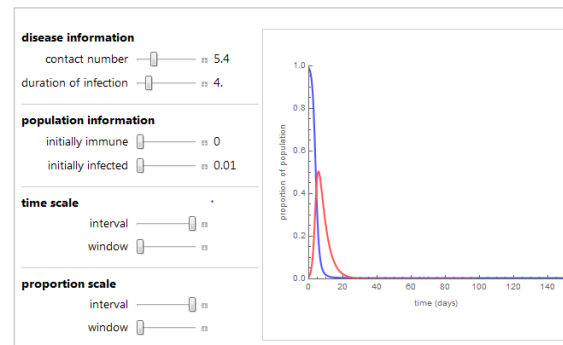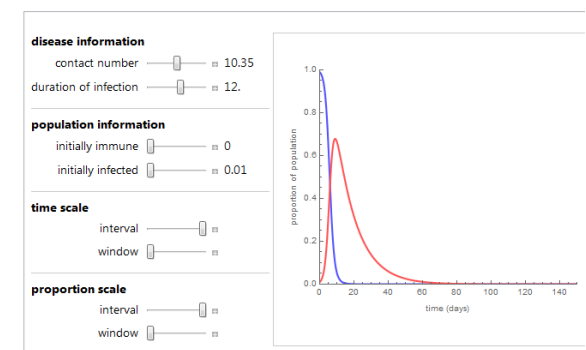**Figure (2B): SIR Epidemic Dynamics of COVID-19 in the World, 10th April 2020**

Figure (3C): SIR Epidemic Dynamics of COVID-19 in the USA, 10th April 2020

DISCUSSION

The situation of COVID-19 pandemic in Egypt as compared to other parts of the world is promising. The transmission rate is smaller than the recovery rate with no exponential growth. Mitigation efforts of Egypt had succeeded in delaying the peak of the curve after the seventh week of first exposure.

Egypt is one of the countries, alongside China[11], to flatten the curve of new infections of COVID-19 pandemic. Egypt has done so without huge outbreaks, without China's draconian restrictions on speech and movement, or economically damaging lockdowns like those in Europe and the United States.[2]
Much rather be ahead of the curve than behind it. To explain, Egypt did not underestimate the problem since the first reported case in Egypt on 8th February, knowing well that COVID-19 is inevitable and started to deal early, to limit transmission and increase recovery. Limiting transmission in Egypt was difficult without the mitigation procedures of the government as the household and social contact is high (three contacts, as the household number is 4 in Egypt).[12, 13]

WHO COVID-19 technical mission in Egypt on March, 5 concluded that considerable efforts have been made by the government in allocating additional dedicated human and financial resources needed to contain the outbreak. Progress has been made in expanding the number of peripheral laboratories that are now able to test for COVID-19 and in engaging overall laboratory capacities.[14]

The mission also added that Egypt's strong disease surveillance system and contact tracing efforts have proven effective in controlling and managing sporadic and clusters of cases before they can spread. Recent border closures now provide an opportunity to enhance screening and rapid testing capacity using a risk assessment approach, in addition to the current well-structured Infection Prevention and Control (IPC) programme that enhances the isolation, quarantine and referral mechanisms, and IPC practices that prevent transmission at all levels to ensure that patients and health workers are protected.[14]

Besides, significant efforts have been made to ensure the public is updated on the current situation, including working with other sectors to reach vulnerable populations. Greater coordination and partnerships with civil society, non-governmental organizations (NGOs), and the media to ensure that the public can make informed decisions, without succumbing to mistrust or the stigma associated with the disease.[15, 16] However, as epidemiologists, we need to be very cautious with our optimism taking into account those who are COVID-19 positive, but have not been tested and the number of people with either mild illness or who are asymptomatic. In a recent report by Vollmer and Bommer, they concluded that the detection rate of COVID-19 new cases is around six percent of the real number of infected individuals globally with wide variations among different countries. The real number could be between 29 and 83 times as high as the official tallies. This means that governments and policymakers need to practice extreme caution when interpreting case numbers for planning purposes and great improvements in the capacity of countries to detect infections and contain the virus.[17]

The trend in reported death rates for COVID-19 has been typical for emerging infectious diseases. At the initial phase of the pandemic, the CFR was reported from a small cohort of hospitalized cases to be 15%.[18] Subsequently, with more available data, the CFR decreased to between 4.3% and 11.0%[19, 20], and recently to 3.4%.[21] One rate was even lower (0.4%; two of 464).[22]

Although the death rate among cases with defined outcome in the current study seems quite higher than the CFR reported globally, it does not mean that there is a high CFR in Egypt. In this study it was calculated as deaths out of cases with defined outcome, the higher the denominator, the lower is the CFR and vice versa. The denominator is usually affected by the policy of testing as it increases when being able to include testing of mild or asymptomatic cases.[23] In the situation of the current study we limited the denominators to diagnosed cases with definite outcomes and not to the total cases making the CFR seems to be overestimated.

CONCLUSION AND RECOMMENDATIONS

Although the epidemic situation in Egypt is not alarming so far, strengthening all the mitigation efforts and regulations of the country with following all the WHO recommendations is necessary for the present time to keep the exposure probability as well as the transmission rate as low as possible.

More studies are needed by utilizing the huge raw data as well as secondary data of COVID-19 pandemic in research. Due to the dynamic nature of the pandemic, more and continuous epidemiological models are needed for forecasting and preparedness in different scenarios.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Wang C, Horby PW, Hayden FG, Gao GF. A novel coronavirus outbreak of global health concern. Lancet. 2020;395(10223):470-3. doi: 10.1016/S0140-6736(20)30185-9.
2. Fernandes N. Economic effects of coronavirus outbreak (COVID-19) on the world economy. 2020. Available from SSRN: https://ssrncom/abstract=3557504 or http://dxdoiorg/102139/ssrn3557504.
3. WHO. Coronavirus disease 2019 (COVID-19): situation report. Geneva: World Health Organization, 2020 72.

4. Zhou Y, He C, Wang L, Ge B. Post-translational regulation of antiviral innate signaling. European journal of immunology. 2017;47(9):1414-26.

5. Barua S. Understanding Coronanomics: The economic implications of the coronavirus (COVID-19) pandemic. SSRN Electronic Journal https://doi org/10/ggq92n. 2020.

6. Worldmeter. COVID-19 coronavirus pandemic. United States: Dadax; 2008 [updated 2020; cited 2020 April 10]. Available from: https://www.worldometers.info/ coronavirus/.

7. MOHP Report of COVID-19, Egypt, 2nd, April,2. Egyptian MOHP: 2020.

8. IBM Corp. Released 2017. IBM SPSS Statistics for Windows VA, NY: IBM Corp.

9. SAS Institute Inc. 2015. SAS/IML® 14.1 User's Guide. Cary NSII.

10. Mathematica [Internet]. Wolfram Research, Inc. Available from: https://www.wolfram.com/mathematica.

11. Zhu ZB, Zhong CK, Zhang KX, Dong C, Peng H, Xu T, et al. [Epidemic trend of corona virus disease 2019 (COVID-19) in mainland China]. Zhonghua Yu Fang Yi Xue Za Zhi. 2020;54(0):E022.

12. Egypt's efforts to contain coronavirus are 'reassuring': Sisi. Ahram online. 2020 Tuesday 31 Mar 2020.

13. STATISTICA. Number of households in Egypt from 2012 to 2017 [cited 2020 April, 2]. Available from: https://www.statista.com/statistics/875743/egyptl-number-of-households/.

14. WHO-EMRO. WHO delegation concludes COVID-19 technical mission to Egypt [Internet]. 2020; 25 March 2020 [cited April, 5]. Available from: http://www.emro.who.int/media/news/ who-delegation-concludes-covid-19-technical-mission-to-egypt.html

15. Al-Mandhari A, Samhouri D, Abubakar A, Brennan R. Coronavirus Disease 2019 outbreak: preparedness and readiness of countries in the Eastern Mediterranean Region. East Mediterr Health J. 2020;26(2):136-7.

16. COVID-19 in Egypt, daily report: Egyptian Ministry of Health and Population; [cited 2020 April, 16]. Available from: http://www.mohp.gov.eg/.

17. Average detection rate of SARS-CoV-2 infections is estimated around six percent [Internet]. University of Goettingen; 2020; [cited 2020 April 8]. Available from: www.uni-goettingen.de/en/606540.html

18. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical feature of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497-506. doi: 10.1016/S0140-6736(20)30183-5.

19. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiologicaland clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395(10223):507-13. doi: 10.1016/S0140-6736(20)30211-7.

20. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. JAMA. 2020. doi: 10.1001/jama.2020.1585.

21. Osborn M, Lucas S, Stewart R, Swift B, Youd E. Briefing on COVID-19. the Royal College of Pathologists, 2019.

22. Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU) [cited 2020 April 12]. Available from: https://coronavirus.jhu.edu/map.html.

23. Rajgor DD, Lee MH, Archuleta S, Bagdasarian N, Quek SC. The many estimates of the COVID-19 case fatality rate. Lancet Infect Dis. 2020. doi: 10.1016/S1473-3099(20)30244-9.