African Multidisciplinary
Journal of Sciences and Artificial Intelligence

ISSN : 0000-0000

Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/AMJSAI.v1i1.3550

Appication of Numerical Simulations to the Study of Spread and Control of COVID-19 in Nigeria

Okorie Charity Ebelechukwu[1], Haruna Yusuf[2], Bala Ma'aji Abdulhamid[3], Hina Aliyu Danladi[4]

[1]Federal University Wukari, Nigeria; [2,3]Abubakar Tafawa Balewa University, Bauchi, Nigeria

[4]Gombe State University, Gombe, Nigeria

okoriec636@gmail.com

Article Info:

Submitted:	Revised:	Accepted:	Published:
Jul 1, 2024	Jul 24, 2024	Jul 27, 2024	Jul 31, 2024

Abstract

Corona virus is a disease that started by putting human being into the state of fear. It is the most dreaded disease that created an indelible mark that all the countries in the world cannot forget in a hurry. The emergency of COVID-19 motivated the researchers into carrying out research work so as to see if there is a way to control its spread thereby preventing the incessant death associated with COVID-19. From the literatures, we observed that some areas have been covered but we observed that quarantine, vaccination and partial immunity were not covered. This prompted this research. The aim is to determine the impact of vaccination and partial immunity on the transmission dynamics of COVID-19. To achieve this, we carried out numerical simulation so as to find out if quarantine, vaccination and partial immunity have impact in the spread and control of COVID-19, using the data we obtained from National Centre for Disease Control, World Meters and from Literatures The analysis was carried with the aid of Maple 2023 software. The results show that quarantine, vaccination and partial immunity has impact in the spread and control of COVID-19. We therefore recommend that incomplete doses of the vaccines should be avoided for effective control of the disease. Health workers should ascertain the health condition of a patient before discharging such patients so as to prevent partial immunity.

Keywords: Numerical simulation, partial immunity, Vaccination, Quarantine, Disease

INTRODUCTION

COVID-19 is a new form of a typical pneumonia. It was first reported in the city of Wuhan in December 2019, and has spread rapidly to other areas of China and multiple countries (Chen, 2019). Corona virus disease is likely to emerge as a watershed moment in the history of the planet. COVID-19, the abbreviation of corona virus disease (2019), is caused by a severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) (WHO, 2019), which hit the globe with a bang. In December 2019, the first outbreak was noticed in Hubei province, Wuhan, China (Hui et al, 2020). On February 11th, 2020, the World Health Organization (WHO) Director-General, Dr. Tedros Adhanom Ghebreyesus, named the disease caused by the SARS-CoV-2 as "COVID-19", and by March 11th, 2020 when the number of countries involved was 114, with more than 118,000 cases and over 4000 deaths, the WHO declared the pandemic status (WHO,2020). The pandemic started with a cluster of patients being admitted in late December 2019 to hospitals with an initial diagnosis of pneumonia and the patients were linked to a seafood and wet animal market in Wuhan, Hubei Province, China (Rothabn and Byrareddy, 2020).The novel corona virus 2019 (2019-nCoV, officially named as severe acute respiratory syndrome corona virus 2 [SARS-CoV-2] by International Committee on Taxonomy of Viruses, belongs to the genus β, with envelope, round or elliptic and often pleomorphic form, and 60–140 nm in diameter. The virus genetically differs considerably from those of SARSr-CoV and MERSr-CoV. Current studies show that the homology between 2019- nCoV and bat-SARS-like corona virus (bat-SL-CoVZC45) is over 85%. When cultured in vitro, 2019-nCoV can be found in human respiratory epithelial cells after about 96 hours, while it takes about 6 days to isolate and culture Vero E6 and Huh-7 cell lines (Global Health Journal,2020). COVID-19 is transmitted from human-to-human via direct contact with contaminated surfaces and through the inhalation of respiratory droplets from infected individuals (Bai et al, 2020). There are different schools of thought behind the origin of COVID-19: some say that it might be of bat origin (Zhou, et al,2020), some say that it might be related to a seafood market exposure (Gao, W., et al.: 2020).

According to the latest research, the novel corona virus is 96% identical at the whole-genome level to a bat corona virus, leading to speculation that this new corona virus may originate from bats (Zhou et al,2020; Wu et al, 2020).

The corona virus is found both in humans and animals and it causes diarrhoea in human beings. COVID-2019 emerged from China in late December. It follows two other corona virus outbreaks, the SARS-CoV and the MERS-CoV. Corona viruses usually circulate among animals but sometimes can jump to humans (Holstein,2020). As of May 27, 2020, 5,656,615 cases of COVID-19 have been reported worldwide, with about 355,355 deaths (The European Centre for Disease Prevention and Control, 2020). In case of this current pandemic COVID-19, according to New York time 2020, some individuals who are infected with the corona virus can spread it even though they have no symptoms. It is also called incubation period (time from exposure to the development of symptoms), reported between 2–14 days (Worldometer,2020)

Despite the fact that there were multiple crises in recent years, such as natural disasters, economic rises, and even epidemics, the corona virus pandemic is the first in 100 years to severely affect the entire world. The economic effects of the COVID-19 Pandemic concern an impending global recession caused by the lockdown of non-essential industries and the disruption of production and supply chains (Wong and Tang (2005).

To slow the spread of COVID-19, the Centre for Disease Control and Prevention (CDC) has recommended that individuals adopt certain preventive health behaviors. These recommendations include hand washing with soap and water or hand sanitizer, keeping a six-feet social distance from other people, and covering the mouth and nose with a cloth face mask when around others (CDC, 2019).

Some studies showed that seeking social support is one of the most common strategies used to deal with the corona virus pandemic (Ogueji and Okoloba (2021);Chew et al (2020))

METHODS

The 10 compartmental model equations, that is equations (1)-(19) are the model equations used in the analysis.

The Model Equations

$$\frac{dS}{dt} = \pi - (1-P_1)(\beta_2 I_A + S\beta_3 I_S)S - (1-P_2)S\beta_1 V + ZV_c + nQ + R\varpi_1 - (\Gamma + \mu_1)S \quad (1)$$

$$\frac{dE}{dt} = (1-p_1)(\beta_{DA} I_A + \beta_{DS} I_S)S + (1-p_2)S\beta_1 V - (\delta + \varpi_2 + \mu_1)E \quad (2)$$

$$\frac{dI_A}{dt} = (1-r)\delta E - (\rho_A + \gamma_A + \omega_1 + \mu_1)I_A \quad (3)$$

$$\frac{dI_S}{dt} = r\delta E - (\rho_S + \mu_S + \gamma_S + \omega_2 + \mu_1)I_S \quad (4)$$

$$\frac{dI_H}{dt} = \alpha_A \gamma_A I_A + \alpha_S \gamma_S I_S + v I_W - (\rho_H + \mu_H + \mu_1)I_H \quad (5)$$

$$\frac{dI_W}{dt} = (1-\alpha_A)\gamma_A I_A + (1-\alpha_S)\gamma_S I_S + mQ - (v + \rho_W + \mu_W + \mu_1)I_W \quad `(6)$$

$$\frac{dR}{dt} = \rho_A I_A + \rho_S I_S + \rho_H I_H + \rho_W I_W - (\varpi_1 + \mu_1)R \quad (7)$$

$$\frac{dV}{dt} = \omega_1 I_A + \omega_2 I_S - (\varphi + \mu_1)V \quad (8)$$

$$\frac{dQ}{dt} = \varpi_2 E - (n + m + \mu_1)Q \quad (9)$$

$$\frac{dV_C}{dt} = \Gamma S - (Z + \mu_1)V_C \quad (10)$$

Table 1: Table of Data for variables and parameters

	Variables and values		Source
1	**N**	221,859,741	World Population Review,2023
2	**S**	126,000	Lin et al (2020)
3	E	60789	Worldmeters,2023
4	I_A	26667	Assumed
5	I_S	35000	Worldmeters,2023
6	I_H	27483	Assumed
7	I_W	15000	Assumed
8	R	70,000	Worldmeters,2023
9	V	24995	Assumed
10	D	3,155	Worldmeters,2023
11	V_C	20,616	National Institute of Health
12	Q	20000	Assumed

Table 2: Table of variables and Parameters values

S/N	Parameters	Values	Source
1	π	0.01888	World Bank Birth rate(2018)
2	P_1	0.0351	Rabajante(2020)
3	β_{DA}	0.000000622	Jummy et al, 2021
4	β_{DS}	0.0000004306	Jummy et al, 2021
5	P_2	0.01255	Rabajante(2020)
6	β_1	0.00000016462	Jummy et al, 2021
7	Γ	0.138	World meters,2023
8	ϖ_1	0.01	Assumed
9	ϖ_2	0.1259	Sanchez and Blower2020)
10	Z	0.0003	World meters,2023
11	n	0.001	Assumed
12	μ_1	0.00712	WorldBank Death rate(2018)
13	δ	0.025	Shaikh et al (2020)
14	r	0.05	Jummy et al,2021
15	ρ_A	0.007	Jummy et al,2021
16	γ_A	0.029389	Jummy et al,2021

17	ω_2	0.0356	Jummy et al,2021
18	ρ_S	0.24701	Jummy et al,2021
19	γ_S	0.12072	Jummy et al,2021
20	ω_2	0.025193	Jummy et al, 2021
21	α_A	0.74087	Jummy et al, 2021
22	α_S	0.82189	Jummy et al, 2021
23	ρ_H	0.0357	Jummy et al, 2021
24	μ_H	$\frac{1}{10}$	Jummy et al, 2021
25	v	0.012277	Jummy et al, 2021
26	ρ_W	0.0001	Jummy et al, 2021
27	μ_W	$\frac{1}{15}$	Jummy et al, 2021
28	μ_S	0.034632	Jummy et al,2021
29	m	0.002	Assumed

RESULTS AND DISCUSSION

Numerical Simulation

We used numerical simulations to illustrate some of the analytical result and verify theoretical predictions of the model (1)-(10) using set of parameter values (Table 1). This parameter values are obtained from the epidemiology of demographic profile of the population which is obtained from literatures. We used Maple 2023 software to run the analysis. The results of the numerical simulation are presented in the figures 1-5 below;

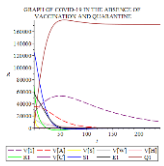

Figure 1: graph of COVID-19 in the absence of quarantine and vaccination

This graph shows that quarantine and vaccination is very important when considering the state of recovery of COVID-19 patients. Looking at the early stage of the graphs, we can see how the recovery graph went down drastically. This occurs because when the virus spread rapidly though the population without measures put in place to control the spread. The increase seen in the graph comes as a result of natural immunity.

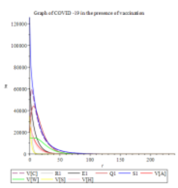

Figure 2: Graph showing the effect of vaccination to COVID-19

From this graph, we observe that before the introduction of vaccines, the graph shows a trend of increase in infection. As soon as vaccination is introduced, the graph shows a decline in the trend of infection which brings increase in recovery of individuals with COVID-19. The graph also shows that there are low hospitalized individuals. This is because as the graph is flattening, it indicates low hospitalized individuals and less strain foe medical resources. This graph shows that vaccination has an impact on COVID-19.

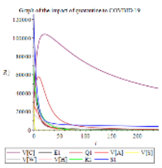

Figure 3: Graph showing the impact of Quarantine on COVID -19. From figure 1, we saw that before quarantine the graph shows an increase in infections. As quarantine is introduced, the rate of new infections start to slow down as infected individuals are isolated and prevented from spreading the virus to other, This shows that quarantine has a great effect on the recovery of COVID-19 patients.

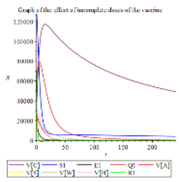

Figure 4: Graph showing the impact of incomplete doses of vaccination

From this graph, we observed that the graph of incomplete vaccination shows less impact on the reduction of spread of COVID-19 This shows that there is need to have complete doses for effective reduction and prevention of COVID-19, We also observe that incomplete doses of vaccination has a great adverse effect on the recovery of COVID-19.

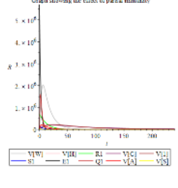

Figure 5: Graph showing the impact of Partial immunity

In this graph, we observe that there are some individuals who have some degree of immunity due to treatment received from the hospital but due to the pressure in the hospital facilities such individuals were discharges without acquiring full immunity thereby slowing down the recovery rate. This shows that Partial immunity has an adverse effect on the state of recovery from COVID-19.

CONCLUTION

The graphs of the numerical simulation show that the control strategies should not be neglected for effective control of COVID-19. Also, incomplete doses of the vaccines and partial immunity should be avoided so as to prevent re-infection of the disease.

REFERENCES

Bai Y, Yao L, Wei T, Tian F, Jin DY, Chen L, Wang M, Presumed asymptomatic carrier transmission of COVID-19, JAMA 2020.

Centres for Disease Control and Prevention. How to Protect Yourself & Others. Available online at: https://www.cdc.gov/coronavirus/2019-ncov/ prevent-getting-sick/prevention.html

Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, Qiu Y, Wang J, Liu Y, Wei Y, Xia Ja, Yu T, Zhang X, Zhang L. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet (London, England). 2020: S0140- 6736(0120)30211-30217.

Chew Q.H,Wel K.C.,Vasoo S., Chew H.C.,Sim K.(2020); Narrative Synthesis of Psychological and Coping Responses towards Emerging Infectious Disease Outbreak in the general Population, Practical consideration for the COVID 19 Pandemic .Singapore Med. J. 2020 July 61 (7).350- 356. https://doi.org/10.11622/smedi-2020046PMID:32241071

Holstein B, Corona virus 101, The Journal for Nurse Practitioners (2020), doi: https://doi.org/10.1016/j.nurpra.2020.03.021.

Hu ZB, Ci C. Screening and management of asymptomatic infection of corona virus disease 2019 (COVID-19). Chin J Prev Med 2020;54:E025. https://doi.org/10.3760/cma.j.cn112150- 20200229- 00220 [Epub ahead of print].

Hu Z, Song C, Xu C, Jin G, Chen Y, Xu X, et al.(2020); Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. Sci China Life Sci 2020;63(5):706e11.

Hui, D.S., Azhar, E.I., Madani, T.A., et al.: Editorial: The continuing 2019-nCo epidemic threat of novel corona viruses to global health—the latest 2019 novel corona virus outbreak in Wuhan, China. Int. J. Infect. Dis. 91, 264–266 (2020) https//doi.org/10.1155/2020/6862516

OguejiI.H.,Okoloba M.M.,DemakoCeccalda B.M.D.(2021); Coping Strategies of Individuals in the United Kingdom during the COVID 19 pandemic. Curr Psychology 2021, Vol 3:1

Rothana HA, ByrareddySN(2020; The epidemiology and pathogenesis of corona virus disease (COVID19) outbreak, J. Autoimmun. 2020;109:102433.

World Health Organization. Rolling Updates on Corona virus Disease (COVID19). Available online at: https://www.who.int/emergencies/diseases/novelcoronavirus-2019/events-as-they-happen 3

World Health Organization Director-General's Opening Remarks at the Media Briefing on COVID-19–11 March 2020. Available online: https://www.who.int/dg/speeches/detail/who-director-general-s-openingremarks-at-the-media-briefing-on-covid.11th March,2020(Accessed on 2nd December,2021)

Wong CY, Tang CS. Practice of habitual and volitional health behaviours to prevent severe acute respiratory syndrome among Chinese adolescents in Hong Kong. J Adolescent Health. (2005) 36:193–200. doi: 10.1016/j.jadohealth.2004.02.024

Worldometers. Coronavirus cases (2020).https://www.worldometers.info/coronavirus/coronavirus- cases/ (accessed 2.04.20

Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, Hu Y, Tao ZW, Tian JH, Pei YY, Yuan ML, Zhang YL, Dai FH, Liu Y, Wang QM, Zheng JJ, Xu L, Holmes EC, Zhang YZ. A new corona virus associated with human respiratory disease in China. Nature. 2020.

Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, et al. SARS CoV-2 viral load in upper respiratory specimens of infected patients. N Engl J Med 2020;382(12):1177e9.