Vol. 11 No. 1 (2023) 87-92 *doi: 10.20473/jpk.V11.I1.2023.87-92*

Why After Fully Covid-19 Vaccinated, We are Still Obliged to Implement Health Protocols: An Evidence-Based on Agent-Based Simulation

Lutfi Rahmatuti Maghfiroh⌧1), Tiodora Hadumaon Siagian2)

1 Department of Statistical Computing Politeknik Statistika STIS, Jalan Otto Iskandardinata 64C Jakarta Indonesia 13330

2 Department of Statistics Politeknik Statistika STIES, Jalan Otto Iskandardinata 64C Jakarta Indonesia 13330

⌧Email: lutfirm@stis.ac.id

ABSTRACT

Background: *The current outbreak of COVID-19 affected many countries in the world, including Indonesia. The Indonesian government has taken various actions to prevent the spread of COVID-19. One of them is by applying the 3M health protocols (wearing masks, washing hands, and maintaining distance). Considering that vaccines are a critical tool in the battle against COVID-19, the Indonesian government began the COVID-19 Vaccination program on January 13, 2021. Unfortunately, many people believe that the vaccines can fully protect against COVID-19 so they are not applying the 3M health protocols anymore. Admittedly the efficiency of vaccines is not completely protective, the virus itself is still mutating and even can spread more massively. Several simulations of the spread of COVID-19 have been carried out by several researchers. However, only a few research has included variables about compliance with health protocols and vaccine programs.* ***Objective:*** *This study aims to provide empirical evidence for health promotion by showing why after fully COVID-19 vaccinated, people are still obliged to implement health protocols.* ***Methods:*** *We conducted 12 scenarios of simulations to understand the effect of complying and not complying with these two programs.* ***Results:*** *The simulation results show that after being fully vaccinated against COVID-19, it is proven that people are still required to implement health protocols such as wearing masks, washing hands, and practicing physical and social distancing because there is still the possibility of contracting the COVID-19 virus and spreading the virus.* ***Conclusion:*** *Our simulation results provide empirical evidence for health promotion by showing why after fully COVID-19 vaccinated, people are still obliged to implement health protocols. This can be evidence for the government and related agencies to educate the public to be more compliant in implementing health protocols so that we can hope that no one will be infected with the COVID-19 virus and everyone can return to their normal activities.*

Keyword: *Agent-based, COVID-19, Health protocols, Simulation, Vaccine.*

INTRODUCTION

The COVID-19 outbreak is currently hitting many countries in the world, including Indonesia. COVID-19 is a new disease caused by the severe acute respiratory syndrome virus or SARS-CoV-2 for short (Satuan Tugas Penanganan COVID-19, 2022). The SARS-CoV-2 virus is a new variant of the Corona Virus which caused the SARS outbreak in 2002-2003. When compared to other Corona Viruses, this new virus is easier to attach to human cells so the ability to infect and spread occurs more quickly. For this reason, various steps have been taken by the government so that the spread of the SARS-CoV-2 Virus can still be handled. One of the important steps taken is to provide referral hospitals in various cities (the list is in (Kementrian Kesehatan RI, 2022). Besides, the socialization of the application of health protocols (Satuan Tugas Penanganan COVID-19, 2020; Center for Disease Control and Prevention, 2022; World Health Organization, 2022a), such as wearing masks, washing hands, and maintaining distance, has also been continuously improved. Moreover, people who are suspected of being infected are asked to carry out isolation.

Some vaccines have been developed to protect people from COVID-19, e.g: The Pfizer/BioNTech Comirnaty vaccine, The Sinovac-CoronaVac vaccine, etc (World Health Organization, 2022b). The first Indonesian vaccination activity was conducted on January 13, 2021 (Kementrian Kesehatan RI, 2021) and until July 27, 2021, only 21.74% of people are vaccinated in the first dosage and

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023

Vol. 11 No. 1, March 2023, 87-92 *doi: 10.20473/jpk.V11.I1.2023.87-92*

from those, only 8.9% of people are fully vaccinated from the national vaccination target on more than 208 million people. Then a booster shot is recommended at least 5 months after completing 2 doses to improve body's protection against COVID-19 especially for people ages 65 years and older. Admittedly these vaccines have various protection effectiveness. None of them has full protection (Mancuso, Eikenberry and Gumel, 2021; Badan Pengawas Obat dan Makanan - Republik Indonesia, 2022). In fact vaccine Antibody can be fades after 6 months (Pan *et al.*, 2021). In some cases, vaccinated people still can be infected (World Health Organization, 2021, 2022c). The different public health conditions among regions in Indonesia and the characteristics of the SARS-CoV-2 virus, which continues to develop and can mutate aggressively, have caused the COVID-19 outbreak in Indonesia to be ongoing.

Various simulation modeling techniques can be used to study the dynamic conditions that exist in society. One of these simulations is an agent-based model simulation. Agent-Based Modeling (ABM) can be used to model interactions within a population so that decision-makers can learn how small changes in behavior and interactions can affect output in the population (Currie *et al.*, 2020). Simulations with ABM have been widely used in various fields (Billari *et al.*, 2006). Various applications of ABM in social, political, and economic science include evacuation modeling simulations, traffic, customer flow management, stock market, operational risk, organizational design, diffusion of innovation, and dynamics of adoption (Bonabeau, 2002). In our study, we used ABM to simulate to show why after fully covid-19 vaccinated, we are still obliged to implement health protocols.

One of the simulations with ABM that can be done is to simulate the spread of the virus by Yang & Wilensky (2011) and Wilensky (1999). This means that agent-based simulations can also be done for COVID-19, which is currently a pandemic. Agent-based simulations are suitable for simulating pandemics (Epstein, 2009). This is also confirmed by Currie et al. (2020) that ABM is stochastic so that it can see the variability of human behavior.

Simulations on the spread of COVID-19 have been carried out by several researchers, one of which is Valdez (2020), but the research only considers the characteristics of the virus (such as the chance of infection, incubation time, severity, mortality rate, and duration of illness), level of physical distancing, number of agents in an area and hospital capacity. The simulation aims to determine the effect of maintaining physical distance on the development curve of the pandemic that occurs. In this simulation, it is assumed that all agents have the same characteristics. However, there are other influencing things such as congenital or comorbid diseases where COVID-19 is known to be 6% more severe and 12% more deadly in comorbid patients (Stokes *et al.*, 2022).

Besides, there are people who are healthy enough to be infected without symptoms known as People Without Symptoms (asymptomatic carriers) (Long *et al.*, 2020; World Health Organization, 2022d). Furthermore, in the simulation, agents who recover from illness are assumed to have immunity forever. This is different from the real condition that the acquired immunity only lasts for two to three months (Long *et al.*, 2020). Some of these variables have been added to previous simulation (Maghfiroh and Siagian, 2020). Another previous study conducted a similar simulation, but their simulation assumed that immune people have forever protection and recovered people cannot be reinfected (Li and Giabbanelli, 2021).

Based on the above discussion, this study aims to build evidence-based on an agent-based simulation and then see their effects on the simulation results. The simulation results can be empirical evidence for health promotion to show why after fully COVID-19 vaccinated, people are still obliged to implement health protocols.

METHODS

The model simulation in this study is based on Agent-Based Modeling (Bonabeau, 2002; MacAl and North, 2017). For some variables, we used data for the Indonesian region, while for other variables that are not yet known for Indonesia, we use generally accepted data. We combine and modify simulation

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023

previous simulations (Yang, C. & Wilensky, 2011; Maghfiroh and Siagian, 2020; Valdez, 2020). Simulation by Valdez (2020) have been taken into account in the simulation such as morbidity (chance of infection, incubation time, severity, mortality rate, duration of illness), level of physical distancing, number of agents in an area, and hospital capacity. Agents represent people in a region. The condition of the agent is divided into six stages, namely the condition of being healthy, infected, sick, severe, immune, and dead. Maghfiroh et al (2020) advanced the simulation by adding some variables, such as comorbid, asymptomatic carrier, and temporary immune. Besides, Yang (2011) has carried out model-based simulations to see the movement of the epidemic but only involved the characteristics of the virus, the tendency for people to move, the tendency to isolate, the tendency to go to the hospital, and the availability of ambulances. This simulation does not yet involve public health protocols and hospital capacity.

In our simulation, we added several new variables, namely: the number of agents with congenital diseases, the severity of agents with congenital diseases, the number of infected agents without symptoms, and the duration of immunity. In the simulation, three levels of the number of agents with congenital diseases were used, namely, 1.5%, 11%, and 63 (World Health Organization, 2020). The severity of the agent with the congenital disease is 12%. For the number of asymptomatic infected agents, we used three levels of numbers, namely 2%, 4%, 6%, 10%, and 14%. The duration of immunity obtained after recovering from illness is 60-90 days. After that, the agent will return to a state without immunity and can become infected again. We also consider health protocol and vaccination conditions as inoculation. This condition will decrease infection chances.

In general, the simulation flow for the spread of COVID-19 can be explained as follows:

a. The initial conditions of the healthy agent: normal, comorbid, and asymptomatic carrier.
b. At the start of the simulation, one agent was infected. (an infected agent can still travel).
c. Randomly depending on the inoculation rate, some agents will be inoculated.
d. Randomly depending on the chance of infection, other agents within the infectious radius will be infected.
e. inoculated infection rate and health protocol will affect infection rate.
f. An infected agent within more than the incubation time will become immune if it includes an asymptomatic carrier and otherwise will become sick (the sick agent will stop activities).
g. A sick agent with a duration of illness for a predetermined duration of illness will become severe. The random chance of being severe depends on the severity that has been determined and the comorbid is 6% more severe. Besides, the sick agent can recover and have immunity.
h. If there is a severe agent and the hospital capacity is full, then this agent may die. However, if space is still available, the agent will be treated in the hospital and the condition depends on the duration of the illness. The randomized chance of a severe agent dying depends on the death rate determined and the comorbid 12% greater chance of dying. Besides, the sick agent can recover and have immunity.
i. The agent which has immunity only lasts for the specified immune time.

Considering that the characteristics of the population of each region in Indonesia may be different, therefore in this study, an agent-based simulation was carried out with 12 different case scenarios. These differences are in the condition of healthy agents, comorbid agents, asymptomatic carrier agents, levels of health protocol maintenance, and inoculation as follows:

#1. initial 1000 agent, asymptomatic 2%, comorbid 1.5%, no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;
#2. initial 1000 agent, asymptomatic 4%, comorbid 11%,no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;
#3. initial 1000 agent, asymptomatic 6%, comorbid 63%, no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;
#4. initial 1000 agent, asymptomatic 10%, comorbid 63%, no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023

Vol. 11 No. 1, March 2023, 87-92 *doi: 10.20473/jpk.V11.I1.2023.87-92*

#5. initial 1000 agent, asymptomatic 14%, comorbid 11%,no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;
#6. initial 1000 agent, asymptomatic 14%, comorbid 63%,no protocol, travel, inoculation chance 50%, inoculated infection rate 50%;
#7. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 50%, travel, inoculation chance 50%, inoculated infection rate 50%;
#8. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 75%, travel, inoculation chance 50%, inoculated infection rate 50%;
#9. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 90%, travel 50%, inoculation chance 50%, inoculated infection rate 50%;
#10. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 90%, no travel, inoculation chance 50%, inoculated infection rate 50%;
#11. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 90%, no travel, inoculation chance 75%, inoculated infection rate 25%;
#12. initial 1000 agent, asymptomatic 14%, comorbid 11%, protocol 90%, no travel, inoculation chance 90%, inoculated infection rate 10%.

RESULTS AND DISCUSSION

Twelve simulations with different conditions on healthy agents, comorbid agents, asymptomatic carrier agents, levels of health protocol maintenance, and inoculation have been discussed above. Meanwhile, the parameter values of other variables in this simulation are considered constant. The simulation was carried out with the help of the NetLogo software (Wilensky, 1999). The simulation results observed were the percentage of the number of affected agents, the percentage of the number of agents who died, and the duration of the outbreak. Simulations are carried out repeatedly to see variations in simulation results. The simulation view can simulation can be obtained from the author.

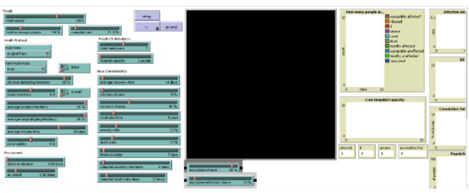

Figure 1. Proposed COVID-19 simulation in NetLogo.

From simulation results we can compare different results affected by different number levels of asymptomatic agents and comorbid agents. This comparison can be seen in Figure 5. From the comparison, we can see that number of asymptomatic agents and comorbid agents make a different number of affected agents, especially dead agents. The more comorbid agent, the more dead agent. Of course, this condition is undesirable in any country in the world. This effect is due to the virus on the co-agent which is 12 times more severe. If these agents do not have special treatment in the hospital (no more capacity in the hospital), it will be fatal for them.

From simulation results on cases 3, 4, and 6, we can compare different results affected by different levels of the asymptomatic agent. The more asymptomatic agent, the faster duration of the pandemic. This is because the infected asymptomatic agent can still move everywhere. This results in the movement of the virus, carried by asymptomatic agents, whether consciously or not, will increase. But what needs to be considered is the number of infected agents that require serious treatment in the hospital. Because of the increasing number of asymptomatic agents, it turns out that the number of severe agents that have to be treated in a short time is increasing. If the hospital capacity is insufficient, the number of agents who die will increase.

From simulation results on cases 5, 7, 8, and 9, we can compare different results affected by the implementation of health protocol in the same different levels of inoculation chance and inoculation infection rate. The more stringent the health protocols are implemented; the fewer agents will be affected and the faster the pandemic duration will be. This is because the more stringent our health protocols are, the less chance we are to be affected and also infect other people. Thus the total number of people affected will be smaller and the pandemic will also end more quickly and no one will be infected with the COVID-19 virus anymore. From this result, we can see that although we get protection from the vaccine (inoculated) but none of those vaccine provide full protection so that we still need to implement health protocol (Li and Giabbanelli, 2021) .

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023

From simulation results on cases 9 and 10, we can compare different results affected by a decision to travel between areas. Traveling to an area will certainly result in the spread of the virus. From the simulation, it can be seen that even though the health protocol is already strict, it turns out that traveling, will still increase the number of agents affected, and in the end, it will extend the duration of the pandemic. These results are in line with previous research which states that limiting travel will reduce the rate of virus spread (Chang *et al.*, 2020; M. J. Hanly *et al.*, 2022).

From simulation results on cases 10, 11, and 12, we can compare different results affected by different levels of inoculation chance and also inoculation infection rate in high level of health protocol. From these simulation results, we can see that the greater chance to be inoculated and the greater protection, it will help us in protecting from the virus. Lower inoculation levels, which represent vaccination rates, may result from high levels of vaccine indecision or low logistics potentially prolonging the time required to achieve adequate population coverage and may even make it impossible to achieve herd immunity (M. Hanly *et al.*, 2022). From this result we can see that combination of high level of health protocol implementation and high protection from vaccine will give us best result of protection.

From all the simulations that have been carried out, we can see that increasing the chance of inoculation by vaccines can help us in dealing with the COVID-19 pandemic. However, protection from Covid-19 vaccines are different (McDonald *et al.*, 2021; Rotshild *et al.*, 2021). Therefore, what we can do is increase the number of people who are vaccinated and also choose the best vaccine so that we can get the best protection. However, it is not the only way to get protection from viruses, because none of those vaccines give us full protection forever (Pan *et al.*, 2021; World Health Organization, 2021, 2022c). In other words, people also remain obligated and continue to apply health protocols and minimize travel, so that people can take care of themselves and shorten the duration of the COVID-19 pandemic.

CONCLUSION

In this study, we carried out 12 Agent-based simulation scenarios to understand the effects of complying and not complying with these two programs (health protocol and vaccination). The simulation results show that after being fully vaccinated against COVID-19, it is proven that people are still required to implement health protocols such as wearing masks, washing hands and practicing physical and social distancing because there is still the possibility of contracting the COVID-19 virus and spreading the virus.

Based on the results of this simulation, the central and local governments, related agencies, COVID-19 task force or other parties can educate the public to be more obedient in implementing health protocols. In addition, the community must also be able to instill self-discipline to maintain the application of health protocols wherever and whenever needed. The more people who are aware of this condition, the more likely it is that no one will be infected with the COVID-19 virus, so that people can live more safely and can return to their normal activities.

REFERENCES

Badan Pengawas Obat dan Makanan - Republik Indonesia (2022) *Penerbitan Persetujuan Penggunaan Dalam Kondisi Darurat Atau Emergency Use Authorization (EUA) Pertama Untuk Vaksin COVID-19*.

Billari, F. C. *et al.* (2006) 'Agent-based computational modelling: An introduction', *Contributions to Economics*, pp. 1–16. doi: 10.1007/3-7908-1721-X_1/COVER.

Bonabeau, E. (2002) 'Agent-based modeling: Methods and techniques for simulating human systems', *Proceedings of the National Academy of Sciences of the United States of America*, 99(SUPPL. 3), pp. 7280–7287. doi: 10.1073/PNAS.082080899/ASSET/15AB2074-4729-491A-B9E6-292A9C40AE31/ASSETS/GRAPHIC/PQ0820808004.JPEG.

Center for Disease Control and Prevention (2022) *How to Protect Yourself & Others*.

Chang, S. L. *et al.* (2020) 'Modelling transmission and control of the COVID-19 pandemic in Australia', *Nature Communications 2020 11:1*, 11(1), pp. 1–13. doi: 10.1038/s41467-020-19393-6.

Currie, C. S. M. *et al.* (2020) 'How simulation modelling can help reduce the impact of COVID-19',

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023

Vol. 11 No. 1, March 2023, 87-92 *doi: 10.20473/jpk.V11.I1.2023.87-92*

https://doi.org/10.1080/17477778.2020.1751570, 14(2), pp. 83–97. doi: 10.1080/17477778.2020.1751570.

Epstein, J. M. (2009) 'Modelling to contain pandemics', *Nature 2009 460:7256*, 460(7256), pp. 687–687. doi: 10.1038/460687a.

Hanly, M. *et al.* (2022) 'Vaccinating Australia: How long will it take?', *Vaccine*, 40(17), pp. 2491–2497. doi: 10.1016/J.VACCINE.2021.07.006.

Hanly, M. J. *et al.* (2022) 'The impact of re-opening the international border on COVID-19 hospitalisations in Australia: a modelling study', *Medical Journal of Australia*, 216(1), pp. 39–42. doi: 10.5694/MJA2.51291.

Kementrian Kesehatan RI (2021) *Program Vaksinasi COVID-19 Mulai Dilakukan, Presiden Orang Pertama Penerima Suntikan Vaksin COVID-19 – P2P Kemenkes RI*.

Kementrian Kesehatan RI (2022) *SIRANAP*.

Li, J. and Giabbanelli, P. (2021) 'Returning to a Normal Life via COVID-19 Vaccines in the United States: A Large-scale Agent-Based Simulation Study', *JMIR Med Inform 2021;9(4):e27419 https://medinform.jmir.org/2021/4/e27419*, 9(4), p. e27419. doi: 10.2196/27419.

Long, Q. X. *et al.* (2020) 'Clinical and immunological assessment of asymptomatic SARS-CoV-2 infections', *Nature Medicine 2020 26:8*, 26(8), pp. 1200–1204. doi: 10.1038/s41591-020-0965-6.

MacAl, C. M. and North, M. J. (2017) 'Tutorial on agent-based modelling and simulation', *https://doi.org/10.1057/jos.2010.3*, 4(3), pp. 151–162. doi: 10.1057/JOS.2010.3.

Maghfiroh, L. R. and Siagian, T. H. (2020) 'SIMULASI BERBASIS AGEN UNTUK MENGEVALUASI PENYEBARAN COVID-19 DI INDONESIA', *Seminar Nasional Official Statistics*, 2020(1), pp. 124–131. doi: 10.34123/SEMNASOFFSTAT.V2020I1.616.

Mancuso, M., Eikenberry, S. E. and Gumel, A. B. (2021) 'Will vaccine-derived protective immunity curtail COVID-19 variants in the US?', *Infectious Disease Modelling*, 6, pp. 1110–1134. doi: 10.1016/J.IDM.2021.08.008.

McDonald, I. *et al.* (2021) 'Comparative systematic review and meta-analysis of reactogenicity, immunogenicity and efficacy of vaccines against SARS-CoV-2', *npj Vaccines 2021 6:1*, 6(1), pp. 1–14. doi: 10.1038/s41541-021-00336-1.

Pan, H. *et al.* (2021) 'Immunogenicity and safety of a third dose, and immune persistence of CoronaVac vaccine in healthy adults aged 18-59 years: interim results from a double-blind, randomized, placebo-controlled phase 2 clinical trial', *medRxiv*, p. 2021.07.23.21261026. doi: 10.1101/2021.07.23.21261026.

Rotshild, V. *et al.* (2021) 'Comparing the clinical efficacy of COVID-19 vaccines: a systematic review and network meta-analysis', *Scientific Reports 2021 11:1*, 11(1), pp. 1–9. doi: 10.1038/s41598-021-02321-z.

Satuan Tugas Penanganan COVID-19 (2020) *Pedoman Pencegahan dan Pengendalian CORONAVIRUS DISEASE (COVID-19) Revisi ke-5 - Protokol | Covid19.go.id*.

Satuan Tugas Penanganan COVID-19 (2022) *Tanya Jawab | Covid19.go.id*.

Stokes, E. K. *et al.* (2022) 'Coronavirus Disease 2019 Case Surveillance — United States, January 22–May 30, 2020', *MMWR. Morbidity and Mortality Weekly Report*, 69(24), pp. 759–765. doi: 10.15585/MMWR.MM6924E2.

Valdez, A. C. (2020) 'NetLogo Web: infections'.

Wilensky, U. (1999) *The CCL*.

World Health Organization (2020) *Media Statement: Knowing the risks for COVID-19*.

World Health Organization (2021) *Episode #49 - Can I get infected after vaccination?*

World Health Organization (2022a) *Advice for the public*.

World Health Organization (2022b) *Coronavirus disease (COVID-19): Vaccines*.

World Health Organization (2022c) *COVID-19 after Vaccination: Possible Breakthrough Infection*.

World Health Organization (2022d) *Pertanyaan jawaban terkait COVID-19 untuk publik*.

Yang, C. & Wilensky, U. (2011) *NetLogo Models Library: epiDEM Travel and Control*.

Received: 16-06-2022, Accepted: 01-08-2022, Published Online: 10-03-2023