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Designing a Science Based Strategy to Prepare for the Next Pandemic

Antong Hou[1], Reto Asmis[2#] and Mark Crowder[3#]

[1]West Carleton Secondary School
[2]Wake Forest University School of Medicine
[3]Vanderbilt School of Medicine
[#]Advisor

ABSTRACT

Since late 2019, the COVID-19 pandemic has ravaged countries and peoples across the globe. As of August 27, 2021, 215 million people have been infected. Most countries have utilized different responses, which significantly influenced the impact of the disease on their respective populations. In this paper, we used an investigative approach to identify the proper measures needed to prepare for the next pandemic. Various National COVID-19 response strategies were identified and compared. In addition, scientific findings of the characteristics of the COVID-19 virus were utilized to identify appropriate responses. It was found that measures including swift lockdowns, border closings, and travel restrictions, accompanied by mask-wearing, mass testing, contact tracing, and healthcare system adjustments were key pieces of pandemic response. In addition, virology research, equipment stockpiling, manufacturing plans, healthcare worker benefits, and healthcare re-education are key to be prepared in advance. These findings are crucial in ensuring that the world is adequately prepared for the next pandemic.

In the past 50 years, there have been countless diseases that have led to global pandemics, localized epidemics, and worldwide health scares. These outbreaks include the 1957 H2N2 Pandemic, the Zaire 1976 Ebola outbreak, the 2002 Chinese SARS outbreak, the 2009 Swine Flu Pandemic (H1N1), and most recently in 2020, the SARS-CoV-2 pandemic. During these different times, response strategies have varied greatly, not just between diseases but between countries.

On December 31st of 2019, the World Health Organization was made aware of a novel coronavirus outbreak in Wuhan, China (WHO, 2021). This class of coronavirus was identified as SARS-CoV-2, which causes an infectious respiratory disease known as COVID-19. COVID-19 spreads through respiratory droplets and aerosols, which can enter the body through the nose, mouth, and eyes. Symptoms of the disease vary depending on the person, ranging from common symptoms like fever and headaches to severe symptoms, including multiple organ dysfunction syndrome. Furthermore, many surviving COVID-19 patients report long-lasting symptoms. For instance, in a study conducted involving 100 (53% male) recently recovered COVID-19 patients, it was found that 60% had ongoing myocardial inflammation (Puntmann et al., 2020).

COVID-19 has heavily affected a large majority of the world, both in terms of public health and the economy. As of August 2021, there have been >200 million confirmed cases, >4 million deaths, and >3.9 billion vaccine doses administered (WHO, 2021). In 2020, it was estimated by the International Monetary Fund that the global GDP would decline by 4.9% (IMF, 2020). Moreover, in 2020, the global unemployment rate rose 1.1 percent, which was significantly greater than the increase in unemployment during the Financial Crisis of 2009 (0.6 percent) (ILO, 2021). Impacts have varied greatly across low- and high-income nations as well as within their own sub-regions. In the future, the question is not if another pandemic will occur, but rather when will it occur? It is in every nation's best interest to be adequately prepared for any future pandemic.

First, the urgency of the situation must be assessed: does the particular disease warrant a response? The infection fatality ratio (IFR) of COVID-19 varies based on a myriad of factors including country, age, and underlying medical conditions. For example, Peru has a case-fatality rate of 9.3% (Johns Hopkins, 2021). Meanwhile, the United States has a much lower rate of 1.7% (Johns Hopkins, 2021). Although seemingly insignificant, if every American was infected with COVID-19, at the current IFR, >5.5 million people would die. Although the IFR does not necessarily influence the specific details of the pandemic response plan, it is a significant factor in deciding if a government should act. With millions around the world at-risk of dying, especially those in developing countries (generally have higher IFRs), it is an irrefutable fact that the COVID-19 pandemic warranted a response at all levels.

Before the reality of an active pandemic occurs, the world must think ahead. The more health officials and scientists know about the possible risks in advance, the more prepared they can be. For example, the SARS-CoV-2 vaccine was developed in under one year. The typical vaccine development timeline is significantly longer, roughly 10-15 years ("Vaccine Development, Testing, and Regulation", 2018). However, when developing a vaccine for SARS-CoV-2, scientists did not start from nothing. There are hundreds of coronaviruses; in fact, SARS and MERS are both coronaviruses (NIAID, 2021). Because of past interactions and continuous research into coronaviruses, scientists already understood certain aspects of the virus's genome, structure, and the key spike protein that binds to the hACE2 receptor (Shang et al., 2020). The new BNT162b2 (Pfizer) mRNA vaccine relies on this information to generate mRNA that produces spike proteins that trigger an immune response, resulting in the formation of antibodies (Health Canada, 2021a). According to WHO, in the past 30 years, 75% of newly emerging pathogens are zoonotic (WHO EMRO, n.d). Therefore, it is recommended that governments invest proper resources into virology research, especially zoonotic virology research. There are countless benefits to conducting rigorous virology research: virologists may be able to identify viruses that have the potential to mutate and infect humans, harmful animal populations can be identified and monitored, and the development of treatments can begin, so they are available when the need arises. It can be argued that virology research labs, specifically BSL-4 labs, create unnecessary risk. Yes, leaks are possible, and exposure has occurred before. However, the lifesaving information that can be obtained far outweighs the risk.

Situations vary, meaning countries must use information and data to assess their individual needs. However, the need to act quickly is universal. Initial WHO estimates placed the basic reproductive number (R_0) of COVID-19 at 2.2-2.7 (WHO, 2020). However, a more recent study state that the median R_0 is 5.7 (Sanche et al., 2020). Since $R_0>1$ and R=5.7, each case of COVID-19 can infect >5 people. With modern travel, one infected individual can spread the disease intercontinentally. Also, with its high infectiousness, one positive case can spark an outbreak. Therefore, countries should react even before a positive case has been identified on their soil. Many African countries exemplify this need, despite being ranked low in health preparedness. For example, the Democratic Republic of the Congo, ranking 161/195 on the Global Health Security Index, has a deaths per 100 000 in population of 0.04 (GHS Index, 2019; Johns Hopkins, 2021). In perspective, the United States, ranking 1/195 on the GHS Index, has a deaths per 100,000 in population of 187.89 (GHS Index, 2019; Johns Hopkins, 2021). The DRC's success was the result of prompt, continental collaboration. On February 4th, 2020, 10 days before the first case of COVID-19 was detected in Africa, the Africa Task Force for Novel Coronavirus was established (Africa CDC, 2020). Dr. Nkengasong, director of the African CDC, stated: "If we do not detect and contain disease outbreaks early, we cannot achieve our developmental goals." Also, on March 15, 2020, many African countries closed their borders, cancelled flights, and introduced lockdowns (Government of South Africa, 2020). In South Africa, a strict, police-enforced lockdown was implemented on March 27, 2020, resulting in a decline from 42% to 4% in the rate of new infections (Smith, 2020). Generally, Africa took swift action, creating task forces and implementing measures that controlled the virus, preventing a high influx. In Europe and North America, action was taken once cases had already risen. Countries must establish organized pandemic task forces, restrict travel/tourism, close borders for nonessential reasons, and implement lockdowns to restrict transmission in the early stages of a pandemic instead of trying to contain numbers that have already risen.

Based on our understanding of the virus, many science-based measures should be implemented instantaneously. If the root of the next pandemic has similar characteristics to SARS-CoV-2, mask wearing, and social distancing must be enforced. SARS-CoV-2 is a respiratory virus, spreading through droplets and aerosols. A particle of SARS-CoV-2 is ~0.1 µm in diameter (Bar-On et al., 2020). It has been argued that masks cannot effectively filter out particles of such a small size. A commonly used example is that of the minimum penetrating aerosol size, 0.3 µm, of the N95 mask (CDC, 2014). However, viral particles do not travel alone and are bound to droplets from speaking or breathing, which are larger than 1 µm. A Beijing observational study of families with at least one positive COVID-19 case found that before the primary case developed symptoms, mask wearing was 79% effective in reducing transmission. Another scientifically sound measure that must be implemented is social distancing. In public facilities, physical distancing of 2 meters should be mandatory. Wells' study, largely accepted by the scientific community, found that respiratory droplets tend to land roughly 3 feet (0.9 meters) from where they were expelled (Wells, 1934). Social distancing also includes a reduction in exposure or contact with others. To illustrate, a contact decrease of 25% in adults <60 years of age resulted in 69% fewer confirmed cases than at the epidemic peak (Matrajt & Leung, 2020). If gatherings must happen, it is crucial that a maximum gathering number that limits the number of people is enforced. Therefore, if one party is infected, only a small number of people are exposed, and it is easier to identify all of the individuals who were in close contact. Governments must encourage and enforce mask wearing and social distancing measures, including size restrictions of private and public gatherings and physical distancing in public.

The clinical onset interval of COVID-19 ranges from 1-14 days; the mean being 5.8 days (McAloon et al., 2020). In the span of 5.8 days, an infected individual can interact with colleagues, friends, family, and strangers out in public, who in turn, repeat the cycle. A mandatory 14 day quarantine, followed by a negative COVID-19 test on all people entering the country, regardless of citizenship, must be implemented to counter the long incubation time. The use of rapid testing must also be used to screen all travelers across borders and airports. In Canada, roughly 26% of COVID-19 cases (as of April 7, 2020) were related to travel exposure (Statistics Canada, 2020). With travel accounting for >25% of cases in certain countries, the mentioned measures must be implemented. Also, these measures allow countries to safely gain the economic benefits of tourism, a sector that lost over $935 billion USD within the first 10 months of 2020 (UNWTO, 2020).

As seen during the COVID-19 pandemic, testing is crucial, regardless of the type of virus. Testing is the only available method to confirm whether an individual does or does not have a virus. Testing provides public health officials with important information regarding who is infected, what areas that are high-risk, and how confirmed cases are trending in a given time period. Many public health measures like contact tracing depend on testing. A common test used during the COVID-19 pandemic was the PCR test that detects the presence of viral RNA. The PCR test requires laboratory analysis, meaning the confirmation process can take multiple days (Kent, 2021). Another widely used test is the antigen "rapid" test, which is cheaper and detects certain proteins of COVID-19 (Health Canada, 2021b). Results from the antigen test can be obtained as quickly as 15 minutes after testing. However, this fast turnaround time is accompanied by less accurate results (Kent, 2021). PCR testing should be conserved for those who are likely to test positive and/or are presenting with COVID-19 symptoms. Meanwhile, antigen rapid testing should be utilized to screen large groups of individuals such as those crossing through borders or airports. Testing must be made available to all. No symptoms do not mean no infection. A South Korean observational study of 199 (69% male) COVID-19 patients, conducted in Gyeongju, Gyeongsangbuk province, 26.6% of patients were asymptomatic (Noh et al., 2020). In addition to asymptomatic numbers, a mean incubation time of 5.8 days means that governments must make testing available to those presenting without symptoms; antigen tests are recommended in this situation. Testing allows public health officials to make informed decisions based on local transmission rates. For example, in South Korea, by April 2020, there were already 612 testing centers. In a future pandemic, governments must establish a sufficient number of testing centers, including sit-down centers, walk-in locations, and drive-through testing. Furthermore, with testing comes the importance of equality. In Nashville, Tennessee, three testing sites were inactive for weeks due to lack of resources like PPE: all three sites were situated in diverse neighborhoods, including the historically black Meharry Medical College (Farmer, 2020). Testing must also be convenient. In the United States, 90% of those earning in the top 25% have paid sick leave, while only 47% of those in the bottom 25% do (BLS, 2020). Governments must create and employ mobile testing teams, who can quickly test large numbers of those at or near their workplaces', so missing work is not a factor in deciding whether or not to get tested. The importance of fast test results is just as crucial as testing itself. During the COVID-19 pandemic, an average of 4.5 days passed between the time of a positive test and the patient notification of the positive result in Ottawa, Canada. Nearby Toronto had a similarly sluggish turnaround time of 4 days (Crawley, 2020). Accompanied by the high possibility of asymptomatic infection and the long clinical onset interval, 4 days is enough time for the infected individual to infect many others in many different locations. In the next pandemic, governments must establish multiple clear lines of communication such as email addresses and phone numbers that are contacted the moment the test has deemed the individual as carrying the virus.

A critical step that follows testing is the use of contact tracing. Once an individual has tested positive, every person whom they have recently interacted with must be identified and contacted. During the COVID-19 pandemic, many contact tracing systems attempted to identify all people who may have been exposed to an infected individual in the preceding 14 days. Once those who have been exposed are identified, the government must enforce self-isolation until the individuals have obtained a negative COVID-19 test. Countries must establish contact tracing centers that contact positive patients regarding their whereabouts, travels, and close contacts. Many Asian countries, like South Korea, utilized phone data surveillance to identify close contacts (Zastrow, 2020). This approach bypasses the struggles of positive cases who are unwilling or unable to provide any close contacts. For example, in a county in North Carolina, USA, 48% of positive cases reported no close contacts (Lewis, 2020). In many countries, especially Western countries, the issue of privacy dismantles the possibility of phone tracking. In countries like the US, a system such as this would be viewed as an invasion of privacy and would not likely be an effective contact tracing tool. Other commonly used, less invasive methods include manual tracing done by public and private institutions, utilizing manual sign-in sheets that obtain the contact information and date of entry of all visitors. Also, some countries have opt-in contact tracing apps like Canada's COVID Alert App, which utilizes Bluetooth to identify possible exposure to other users, who have inputted a specific code signaling that they have tested positive. The next pandemic must utilize comprehensive contact tracing methods to reduce mass transmission. It is recommended that regions use interconnected contact tracing systems. In areas where privacy is of high concern, it can be optional; however, only those utilizing the service may benefit. Instead of each institution trying to contact trace manually, the best tool is a digitized platform utilized by all public institutions and all participating private institutions that allows for the flow and sharing of information. This digitized system must also be connected to testing centers. Ergo, when an individual tests positive, all institutions whom the individual has visited within the past 14 days are notified, and all participating individuals who may have been exposed are also automatically contacted by both phone and email.

Around the world, healthcare systems have been stretched thin because of the COVID-19 pandemic. One primary issue is the maximum capacity of healthcare systems. For example, in 2018, the United States had 728 000 medical and surgical hospital beds (2.2 per 1 000 in population) (Arnos & Blavin, 2021). However, only 36% of these beds were unoccupied on a given day, resulting in a remaining 0.8 unoccupied beds per 1 000 in population (Arnos & Blavin, 2021). As of August 2021, the United States has had >37 million positive COVID-19 cases (>112 per 1000 in population). Of these 37 million positive cases, >2.5 million have resulted in hospitalization (CDC, 2021). Using these numbers, in the United States, there are roughly 7.6 COVID-19 hospitalizations per 1000 in population. Even with COVID-19, other medical emergencies such as heart attacks and car accidents still occur, yet there are fewer available beds due to the high COVID-19 patient volume. It is clear that even with a healthcare system as large as the United States, it is easy to become overwhelmed during a pandemic. In 2017, 14.6 million elective inpatient and outpatient procedures were performed (Best et al., 2020). During the next pandemic, it is crucial that healthcare systems prioritize critical patients, meaning that elective operations must see a temporary reduction or halt. However, it was estimated that the 14.6 million elective procedures in 2017 resulted in an annual net income of $47.1 to $61.6 billion (Best et al., 2020). Therefore, governments must provide hospitals with sufficient financial support to offset the costs of cancelling elective procedures. Governments must also establish areas where non-urgent patients can be diverted, for example, opening temporary clinics in large public facilities. In addition, proper staffing is difficult during pandemics. Long hours, stress, and burnout can drive healthcare workers out of the system. By the end of 2020, in Canada, job vacancies in the healthcare sector hit 100 300, a number 53% larger than in 2019 (Statistics Canada, 2021). The COVID-19 pandemic will leave an even larger impact on staff shortages globally. The Registered Nurses' Association of Ontario (RNAO) reported that 13% of registered nurses aged 26-35 are likely to leave the profession after the pandemic (RNAO, 2021). These young nurses are the future of the Canadian healthcare system. However, highly experienced healthcare workers are also leaving. The same RNAO report stated that 4.5% of late career nurses—nurse executives, advanced nurses, and college faculty—are planning to retire now or after the pandemic (RNAO, 2021). Governments must ensure that healthcare workers are taken care of. They must be given sufficient pay and mental health leave. Hospitals must also be provided with the proper resources to ensure sufficient staffing. Current healthcare workers must also be reeducated to potentially fill the shortages in the next pandemic. For example, before or during the pandemic, non-ICU nurses may attend training sessions that familiarize them with the operations conducted in ICUs should the need arise. To continue, healthcare systems have experienced shortages in equipment and medical supplies. An example is India, where the supply of ventilators is <50% than the number actively required (Tarun, 2021). Governments must stockpile adequate amounts of medical supplies to prepare for the next pandemic, however, many items like drugs and ventilators may not respond well to long-term storage. Ergo, the proper plans must be put in place to allow for the mass production of essential supplies. For example, the American Defense Production Act, which provides emergency authority to the President of the United States to direct domestic industries. Countries must implement similar laws. Before the next pandemic arrives, governments must have a plan outlining who they will direct to manufacture which supplies.

During pandemics and the COVID-19 pandemic specifically, it is crucial that governments and public health officials move society away from the notion that no symptoms is indicative of no infection. As stated, 26.6% of COVID-19 patients are asymptomatic (Noh et al., 2020). Focusing on asymptomatic infection is especially critical towards the end of a pandemic response. As a large percentage of the population becomes vaccinated, and as people have lived in the pandemic-era for long enough, the virus is seen as less of a threat. For example, the July 20, 2021 Axios-Ipsos poll found 39% of Americans believe that resuming their pre-pandemic lives would be a "large or moderate risk to their health," which is 33 points below the share in April 2020 (Jackson, 2021). This drop in concern is dangerous as the 7-day American COVID-19 average surged from 10 608 on July 5, 2021 to 124 470 on August 9, 2021. Nobody should let their guard down, especially as variants like the Delta Covid variant arise. Therefore, as vaccinations increase and numbers start to slow, restrictions must be maintained. If observation allows, restrictions may be eased, however, they should not be eliminated or made lenient. For example, as cases are on a steady decline, governments may increase the allowed size of social gatherings, however, restrictions will still enforce a maximum, safe gathering size.

In conclusion, during the next pandemic, governments must begin by promptly implementing lockdowns, travel restrictions, and border closings to mitigate early transmission. Science based measures such as mask wearing and physical distancing must also be enforced. Then, high volume testing of the population must be conducted, and the collected data must be utilized with comprehensive contact tracing systems to reduce and identify exposure and transmission. Before the next pandemic, governments must continue or begin to fund virology research, to obtain valuable knowledge. Governments must also prepare healthcare systems for an influx in patients and must have concrete plans to ensure supply needs are met; during the pandemic, governments must actively assess the state of healthcare systems and the appropriate support measures, which can be but are not limited to external clinics, direction of private manufacturers, and the cancellation of elective procedures. Once the pandemic is beginning to slow down, it is crucial that restrictions and measures are maintained.

References

Africa CDC. (2020, March 17). Africa CDC establishes continent-wide task force to respond to global coronavirus epidemic. Retrieved from https://africacdc.org/news-item/africa-cdc-establishes-continent-wide-task-force-to-respond-to-global-coronavirus-epidemic/

Jackson, C., Newall, M., & Yi, J. (2021, August 17). Most Americans support requiring masks in public places, yet few report experiencing actual employer or government mandates. Retrieved from https://www.ipsos.com/en-us/news-polls/axios-ipsos-coronavirus-index

Bar-On, Y. M., Flamholz, A., Phillips, R., & Milo, R. (2020). SARS-CoV-2 (COVID-19) by the numbers. ELife, 9. doi:10.7554/elife.57309

Best, M. J., Mcfarland, E. G., Anderson, G. F., & Srikumaran, U. (2020). The likely economic impact of fewer elective surgical procedures on US hospitals during the COVID-19 pandemic. Surgery, 168(5), 962-967. doi:10.1016/j.surg.2020.07.014

Blavin, F., & Arnos, D. (2021, February 26). Hospital Readiness for COVID-19. Retrieved from https://www.rwjf.org/en/library/research/2020/03/hospital-readiness-for-covid19-analysis-of-bed-capacity-and-how-it-varies-across-the-country.html

BLS. (2020). EMPLOYEE BENEFITS IN THE UNITED STATES – MARCH 2020. Retrieved from https://www.bls.gov/news.release/pdf/ebs2.pdf

CDC. (2014, June 06). NIOSH Guide to the Selection & Use of Particulate Respirators. Retrieved from https://www.cdc.gov/niosh/docs/96-101/default.html

CDC. (2021, August 13). COVID Data Tracker Weekly Review. Retrieved August 19, 2021, from https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/index.html

Crawley, M. (2020, November 26). Delays, conflicts and confusion hampered Ontario's COVID-19 response: Auditor general | CBC News. Retrieved from https://www.cbc.ca/news/canada/toronto/ontario-covid-19-lab-testing-case-management-auditor-report-1.5814949

Farmer, B. (2020, April 02). The Coronavirus Doesn't Discriminate, But U.S. Health Care Showing Familiar Biases. Retrieved from https://www.npr.org/sections/health-shots/2020/04/02/825730141/the-coronavirus-doesnt-discriminate-but-u-s-health-care-showing-familiar-biases

GHS Index. (2019). The Global Health Security Index. Retrieved from https://www.ghsindex.org/

Government of South Africa. (2020, March 26). Disaster Management Act: Regulations to address, prevent and combat the spread of Coronavirus COVID-19: Amendment. Retrieved from https://www.gov.za/documents/disaster-management-act-regulations-address-prevent-and-combat-spread-coronavirus-covid-19

Health Canada. (2021, May 05). Pfizer-BioNTech COVID-19 vaccine: What you should know. Retrieved from https://www.canada.ca/en/health-canada/services/drugs-health-products/covid19-industry/drugs-vaccines-treatments/vaccines/pfizer-biontech.html

Health Canada. (2021, August 11). Testing devices for COVID-19: Antigen testing devices. Retrieved from https://www.canada.ca/en/health-canada/services/drugs-health-products/covid19-industry/medical-devices/testing/antigen-devices.html

ILO. (2021). COVID-19 and the world of work. Seventh edition. 1-35. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/briefingnote/wcms_767028.pdf.

IMF. (2020, June 01). World Economic Outlook Update, June 2020: A Crisis Like No Other, An Uncertain Recovery. Retrieved August 19, 2021, from https://www.imf.org/en/Publications/WEO/Issues/2020/06/24/WEOUpdateJune2020

Johns Hopkins. (2021). Mortality Analyses. Retrieved from https://coronavirus.jhu.edu/data/mortality

Kent, C. (2021, May). What are the different types of Covid-19 test and how do they work? Retrieved August 19, 2021, from https://www.medicaldevice-network.com/features/types-of-covid-19-test-antibody-pcr-antigen/

Lewis, D. (2020). Why many countries failed at COVID contact-tracing — but some got it right. Nature, 588(7838), 384-387. doi:10.1038/d41586-020-03518-4

Matrajt, L., & Leung, T. (2020). Evaluating the Effectiveness of Social Distancing Interventions to Delay or Flatten the Epidemic Curve of Coronavirus Disease. Emerging Infectious Diseases, 26(8), 1740-1748. doi:10.3201/eid2608.201093

Mcaloon, C., Collins, Á, Hunt, K., Barber, A., Byrne, A. W., Butler, F., . . . More, S. J. (2020). Incubation period of COVID-19: A rapid systematic review and meta-analysis of observational research. BMJ Open, 10(8). doi:10.1136/bmjopen-2020-039652

NIAID. (2021, August 18). Coronaviruses. Retrieved August 19, 2021, from https://www.niaid.nih.gov/diseases-conditions/coronaviruses

Noh, J. Y., Yoon, J. G., Seong, H., Cheong, H. J., Kim, W. J., & Song, J. Y. (2020). Journal of Infection, 81(5). doi:https://doi.org/10.1016/j.jinf.2020.05.035

Puntmann, V. O., Wieters, I., & Carerj, L. (2020, November 01). Outcomes of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From COVID-19. Retrieved August 19, 2021, from https://jamanetwork.com/journals/jamacardiology/fullarticle/2768916

RNAO. (2021). Results of nursing survey point to an alarming exodus from the profession following the pandemic. Retrieved from https://rnao.ca/news/results-nursing-survey-point-alarming-exodus-profession-following-pandemic

Sanche, S., Lin, Y. T., Xu, C., Romero-Severson, E., Hengartner, N., & Ke, R. (2020). High Contagiousness and Rapid Spread of Severe Acute Respiratory Syndrome Coronavirus 2. Emerging Infectious Diseases, 26(7), 1470-1477. doi:10.3201/eid2607.200282

Shang, J., Wan, Y., Luo, C., Ye, G., Geng, Q., Auerbach, A., & Li, F. (2020). Cell entry mechanisms of SARS-CoV-2. Proceedings of the National Academy of Sciences, 117(21), 11727-11734. doi:10.1073/pnas.2003138117

Smith, E. (2020, April 15). South Africa extends lockdown but offers roadmap for reopening. Retrieved from https://www.cnbc.com/2020/04/15/south-africa-extends-lockdown-but-offers-roadmap-for-reopening.html

Statistics Canada. (2020, April 08). This Just the Facts article highlights statistics on travel-related COVID-19 cases in Canada using case-level data (Detailed confirmed cases of coronavirus disease (COVID-19) (Preliminary data)) and travel data (Frontier Counts). Retrieved from https://www150.statcan.gc.ca/n1/pub/89-28-0001/2018001/article/00018-eng.htm

Statistics Canada. (2021, March 23). Job vacancies, fourth quarter 2020. Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/210323/dq210323b-eng.htm

Tarun, B. (2021, April 21). India has less than 50% of the ventilators than needed for Covid-19 treatment: Ashok Patel, Max Ventilators. Retrieved from https://www.financialexpress.com/lifestyle/health/india-has-less-than-50-of-the-ventilators-than-needed-for-covid-19-treatment-ashok-patel-max-ventilators/2237378/

UNWTO. (2020, December). WORLD TOURISM ORGANIZATION. Retrieved August 19, 2021, from https://www.unwto.org/impact-assessment-of-the-covid-19-outbreak-on-international-tourism

Vaccine Development, Testing, and Regulation. (2018, January 17). Retrieved August 19, 2021, from https://www.historyofvaccines.org/content/articles/vaccine-development-testing-and-regulation

Wells, W. F. (1934). On Air-Borne Infection*. American Journal of Epidemiology, 20(3), 611-618. doi:10.1093/oxfordjournals.aje.a118097

WHO. (2020, June 5). What do we know about SARS-CoV-2 and COVID-19? Retrieved from https://www.who.int/docs/default-source/coronaviruse/risk-comms-updates/update-28-covid-19-what-we-know-may-2020.pdf?sfvrsn=ed6e286c_2

WHO. (2021, August 17). About the virus. Retrieved August 19, 2021, from https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/novel-coronavirus-2019-ncov

WHO. (2021, August). WHO Coronavirus (COVID-19) Dashboard. Retrieved August 19, 2021, from https://covid19.who.int/

WHO EMRO. (n.d.). Eastern Mediterranean Region. Retrieved August 19, 2021, from http://www.emro.who.int/fr/about-who/rc61/zoonotic-diseases.html

Zastrow, M. (2020). South Korea is reporting intimate details of COVID-19 cases: Has it helped? Nature. doi:10.1038/d41586-020-00740-y