ISSN 2581 – 4346

Available Online at www.ijms.co.in
**Innovative Journal of Medical Sciences 2022; 6(2):1-11**

**RESEARCH ARTICLE**

# Booster doses of COVID-19 vaccine: Rationales, implications and way forward for African countries

Seyi Samson Enitan[1]*, Esther Ngozi Adejumo[1], Abah Michael Idoko[2], Ifeoluwapo O. Asekun-Olarinmoye[3], Saratu Omagbemi Ajike[3], Kester Awharentomah Digban[4], Ayodeji Olusola Olayanju[5], Stephen Olaosebikan Makanjuola[6], Rufus Olusegun Animashaun[7], Emmanuel Olusegun Ileoma[1], Jamiu Monsur Olalekan[8], Oluwaseyi Emmanuel Oluwafemi[1], Imoleayo Elijah Olorunnisola[1], Oluyemisi Ajike Adekunbi[1]

*[1]Department of Medical Laboratory Science, Babcock University, Ilishan-Remo, Nigeria, [2]Department of Hematology and Blood Group Serology, Federal College of Veterinary and Medical Laboratory Technology, Vom, Nigeria, [3]Department of Public Health, Babcock University, Ilishan-Remo, Nigeria, [4]Department of Medical Laboratory Science, Novena University, Ogume, Nigeria, [5]Department of Medical Laboratory Science, Afe Babalola University, Ado-Ekiti, Nigeria, [6]Department of Medical Microbiology and Parasitology, Olabisi Onabanjo University Teaching Hospital, Ago-Iwoye, Nigeria, [7]Department of Basic and Allied Sciences, Babcock University, Ilishan-Remo, Nigeria, [8]Department of Medical Microbiology and Parasitology, University of Osun Teaching Hospital, Oshogbo, Nigeria*

**Received on: 20 Feb 2022; Revised on: 30 Mar 2022; Accepted on: 20 Apr 2022**

## ABSTRACT

To contain a pandemic, access to an effective and safe vaccine is a global public health necessity. However, an effective and safe vaccine will not protect against a disease, unless it is given to susceptible persons in the proper dosage and in a timely manner. Since the commencement of the Coronavirus pandemic, every country has been attempting to develop or obtain a vaccine to safeguard their citizens. Because many developing countries, particularly those in Africa, lack the technological capacity to manufacture vaccines, their best option is to purchase one. As a result, many African countries have been able to obtain the initial dose of COVID-19 vaccines, but obtaining the booster doses has proven difficult for many. For multiple-dose vaccines, the interval between doses is crucial to reaping the full advantages of any specific vaccine. At the moment, public health officials are afraid that delay in receiving booster doses will allow the coronavirus to outsmart immunization efforts. While some argue that delaying booster doses will allow host immunity to wane, potentially leading to the emergence of a new, more contagious variant of concern (VOC) that may defeat the vaccine and grounds already conquered, others argue that up to 3 months between doses of two approved vaccines should be allowed instead of the one month studied in vaccine clinical trials. In ananxious attempt to stem the massive increase in confirmed cases and to prevent the spread of a new, more contagious variant of the virus, the highly developed and rich countries have continued to make concerted efforts to get as many people as possible vaccinated with multiple number of doses, without considering the poor COVID-19 vaccine supply chain or the fragile health systems of resource-limited countries like those in Africa. The purpose of this review is to look at the rationales for COVID-19 vaccine booster doses, supply chain bottlenecks, implications and recommendations for African countries.

**Keywords:** Africa, Booster doses, Bottlenecks, COVID-19 vaccine, Supply chain

***Corresponding Author:**
Seyi Samson Enitan,
E-mail: enitans@babcock.edu.ng

## INTRODUCTION

The COVID-19 pandemic, now in its 3rd year, has decimated the whole world and radically

altered how we live our daily lives.[1] There have been 474,659,674 confirmed cases of COVID-19 worldwide as of March 24, 2022, with 6,103,355 deaths.[2] Meanwhile, as of March 28, 2022, about 11.16 billion COVID-19 vaccine doses had been administered globally in an attempt to halt the pandemic.[3] So far, only 64.2% the world's population and 14.4% of low-income nations had received at least one dose of the vaccine (https://ourworldindata.org/covid-vaccinations).

Since the dawn of time, vaccines have continued to play an unparalleled role in stopping the spread of infectious diseases all across the world. The development of vaccines to prevent infection with the Severe Acute Respiratory Syndrome Coronavirus Type 2 (SARS-CoV-2) is the most viable strategy for containing the COVID-19 pandemic. A number of safe and efficient COVID-19 vaccines have been created in record time.[4,5] The successful development and deployment of a number of vaccines has given the world hope that the pandemic may soon be contained, and a booster dose will help to combat the several evolving variants.[6] Moderna, Pfizer-BioNTech, and Johnson & Johnson's Janssen are the three main COVID-19 vaccines that are licensed for use in the United States for protection against COVID-19.[7,8] However, like with most vaccines, immunity fades over time, and this, combined with the emergence of SARS-CoV-2 variants, has resulted in an upsurge in the number of cases recorded till date.[9,10]

Generally speaking, an ideal vaccine should be immunogenic, potent, safe, and capable of conferring long-lasting protection in recipients (usually only with a single dose). Unfortunately, this is not the case with the COVID-19 vaccine, which require a second, third, fourth, or fifth dose in some cases to ensure long-term protection, depending on the age and immune status of the individuals. So far as rightly observed, the COVID-19 vaccine confers only temporary protection that must be reinforced afterwards with multiple doses, but this is not without the logistic problem of regularly reaching those in need of immunization in the face of shortage in global vaccine supply.[10] Interestingly, amidst various fears, the COVID-19 booster doses have been proven to be safe and to boost the levels of SARS-CoV-2-specific neutralizing antibodies that are cross-reactive with contemporary variant of concerns (VOCs). This is especially critical for the elderly and immunocompromised people who are at the greatest risk of the severe COVID-19 infection.[5,8,11,12]

Booster doses are used when immunity and clinical protection in a vaccinated population has decreased below a rate regarded sufficient over time after the initial vaccination series. When a vaccine's effectiveness has been proven to be insufficient, a booster dosage is used to restore it.[13,14] In target populations where the immune response rate following the typical main series is deemed unsatisfactory, more vaccine doses may be required as part of an extended primary series. In the first series, an extra dose is given to optimize or increase the immune response in order to achieve high disease resistance. Immunocompromised people, in particular, are more likely to fail to produce a protective immune response after a typical primary series, but older adults can also have insufficient responses too.[8,15]

For multiple-dose vaccines, the interval between doses is crucial to get the full benefits of any specific vaccine.[10] Meanwhile, public health specialists are becoming concerned that unnecessary delay between doses may allow the coronavirus to outsmart immunization efforts.[16,17] While some argue that delaying booster doses will allow host immunity to wane, potentially leading to the emergence of a new, more contagious variant of concern (VOC) that will defeat the vaccine and grounds already conquered, others argue that instead of the one (1) month used in vaccine clinical trials, up to 3 months should be permitted between doses of two approved vaccines.[18]

In a desperate attempt to stem the massive increase in confirmed cases, and startled by the spread of a new, more contagious variant of the virus (once Delta, then Omicron, and now Deltamicron),[19-21] the developed and wealthy countries have continued to make concerted efforts to vaccinate as many of their citizens as possible, without considering the poor COVID-19 vaccine supply chain and fragile health systems of most developing and less developed countries.[20,22,23]

Interestingly, although the largest-ever COVID-19 vaccine immunization campaign in Africa is under underway with over 22 million doses being distributed in 49 countries across the continent, whether a significant number of the African people will get the required the number of doses to achieved full protection against the virus is a serious public health concern. So far, only 1% of the 1.3 billion COVID-19 vaccines distributed worldwide have been administered in Africa, down from the initial 2%. Most African countries are now experiencing difficulties with vaccine availability and accessibility. At the moment, only 1% of the vaccines used in Africa are produced on the continent of 1.3 billion people.[14] This is very disturbing and worrisome for public health experts.[24] This current review attempts to take a look at the rationales for the booster doses, supply chain bottlenecks, implications, and way forward for the African countries.

## RATIONALES FOR BOOSTER DOSES

According to Maragakis and Kelen,[25] a second, third, fourth, or fifth dose of COVID-19 vaccine is given after the protection offered by the initial shot(s) has begun to wane or diminish over time. The booster aids in the maintenance of sufficient protection against the severe coronavirus infection.[26] COVID-19 vaccine boosters have been approved by the US Food and Drug Administration (FDA) and recommended by the US Centers for Disease Control and Prevention for most people as soon as they are eligible. The protection provided by FDA-approved and authorized vaccines is excellent, albeit after 2 months for the Johnson & Johnson vaccine, and 5 months for the Moderna and Pfizer vaccines, it begins to diminish. However, emerging data have shown that a booster dose can improve immunity, even against the delta and omicron variants.[7,8,11,27,28]

When compared to only being partially vaccinated, two studies released by the CDC reported that being fully vaccinated (getting both doses of the Moderna or Pfizer vaccine or one Johnson & Johnson vaccine) plus receiving a booster provides greater defense against severe disease, hospital stay, and mortality associated with SARS-CoV-2 infection.[8] According to the findings, the booster vaccine provides better protection against the delta and omicron variants than being only partially immunized or not at all.[15,25]

According to the Centre for Disease Control and protection,[7,8] those who have been vaccinated should get a booster dose if they are eligible, and maintain their COVID-19 immunizations up to date. The major purpose of immunization amidst the pandemic is to protect against serious illness, hospitalization, and death and booster doses appear to lessen vulnerability to COVID-19 mutations. However, they are only required if there is evidence of inadequate long-term defense against these disease outcomes. Vaccine products, target populations, the circulating SARS-CoV-2 virus (in particular variants of concern - VoC), and the degree of exposure may all influence the extent of fading immunity and the requirement for booster shots. The recent development of the Omicron variant and the Deltacron recombinant virus emphasizes the importance of COVID-19 vaccine and boosters. COVID-19-related hospitalizations have been reported to be drastically reduced after the third, fourth, and fifth doses.[29-31] It is now obvious that the earlier one is immunized, the better one's immunity and protection against COVID-19.[27] The importance of booster doses cannot be overstated. The first reason is that if one does not respond, or if one belongs to a group of people who did not respond adequately to the first two doses, a third dose may be required because the first two failed to do what they should in otherwise healthy people. The second reason, a third dosage may be required is if a person's immunity begins to wane, worsen, or decline over time after being vaccinated. The third reason a person could need a third; fourth or fifth dose is if the vaccine is less effective against any of the emerging variant of concern (VoC).[32]

## COUNTER OPINIONS

The use of booster doses is controversial. It is common knowledge that a lack of vaccine coverage allows the virus to proliferate. When a virus infects and reproduces in tens of thousands of people, it has the ability to mutate, leading to

the development and emergence of new variants. There are now multiple Coronavirus variants in circulation, including alpha, beta, gamma, delta, omicron, and now Deltacron, which are all considered variants of concern (VOCs). The VOCs all came from places with high levels of viral transmission, which is no coincidence.[33,34] Experts believe that we must get ahead of the virus if we are to avoid more VOCs. According to GAVI,[35] there is no urgent need to give a patient a third, fourth, or fifth COVID-19 vaccine dose in wealthy nations like the United Kingdom. Rather than starting a booster program, scientists believe it would be wiser to give such doses to countries with low coverage. This is critical because the world will never actually be able to escape this pandemic unless there is a widespread vaccine coverage.

Equity issues at the national, regional, and global levels remain crucial in guaranteeing immunization of high-priority populations in every country, despite a continuous global vaccine supply constraint.[36] According to some experts, global vaccine inequity is a strong reason why booster programs should be discouraged for the time being, because only about 1–5% of the population in resource limited countries has received the first/second doses of the vaccine, compared to the well developed countries with high vaccine coverage.[37,38] As a result, the current focus for vaccine supply should be on protecting those who have are yet to receive the initial dose of the vaccine.[39-41] This will minimize transmission, reduce the risk of new variants arising, and give us more time to evaluate the evidence to see if booster doses are needed in the future. Experts believe that no one will be safe unless everyone is vaccinated and protected against the virus as vaccination coverage increases. And what this really means is that doses are being delivered to areas of the world that have not received enough in the past. Experts believe that improving coverage of the initial vaccine series should take precedence over booster vaccination[15] and factors that should be considered before initiating a booster program should including the following among others: 1) Declining immunity,[15,42] 2) vaccine success,[15,26,43] 3) global vaccine supply and equity,[15,36,40,41] and 4) availability of data for policymakers.[40,41]

## COVID-19 VACCINE INEQUITY

Demand for COVID-19 vaccine has long outpaced supply, and distribution increasingly favors high-income countries over low- and middle-income ones.[36] About 78% of the population of the high-income countries had received at least one dose of the vaccine which is on the high side compared to 10% in low-income countries [Figure 1]. Despite the fact that COVID-19 is here to stay (due to emergence of new variants), fair access to the most effective COVID-19 vaccines remains crucial. Vaccine equity means that these doses are delivered evenly throughout all countries depending on need, regardless of the recipient's country or wealth. Every government must prioritize health workers, other critical frontline workers, and those who are most vulnerable to the virus or at danger of catching it.[1] Production capacity and supply remained a major limitation on the pace of national vaccination campaigns in the first quarter of 2021.[44,45]

## DRIVERS OF COVID-19 VACCINE INEQUITY

This review identified two major drivers of COVID-19 Vaccine inequity:

### Production disruption

One of the main drivers of vaccine inequities is production disruption. When it comes to justifying supply delays, manufacturers usually point to production issues. Pfizer, for example, agreed to deliver 350 million doses to the European Union (EU) by the end of September 2021, but announced a temporary halt in supply in January 2021 to increase future production. This disruption has negatively affected immunization coverage

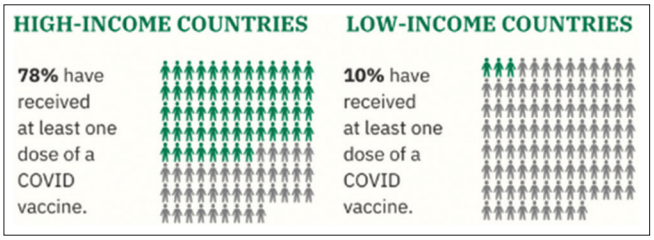


**Figure 1:** A pictorial representation of COVID-19 vaccine uptake in high-income and low-income countries[1]

in many countries including Poland and Romania that received only half of the anticipated volume in February, 2021. Similarly, in the European market, AstraZeneca has also had production challenges. Due to low cell culture yields, the company announced in late January 2021 that it will restrict COVID-19 vaccine supplies to the EU in the first quarter. Furthermore, in the second quarter of 2021, AstraZeneca announced that it will only be able to supply half of the vaccine it was required to sell to the EU, resulting in a 90 million dose reduction.[36,44]

### Underfunding of COVAX

Underfunding of COVAX is another major driver of vaccine inequities. Currently, the Gavi COVAX facility is the main pillar of the access to COVID-19 Tools (ACT) Accelerator. It is the sole mechanism that strives to assure international access to viable vaccine candidates and provides a reasonable and fair distribution logistics amongst states. It is essentially a collective purchasing program in which participating countries negotiate supply contracts with manufacturers on their behalf. Vaccines will be provided to 25 self-funding countries (middle and high-income countries) for 10%–50% of their populations, depending on their financial commitments to the system. Vaccines will also be distributed to 20% of the population in 92 low- and middle-income countries (LMICs) that qualify for donor funding.

COVAX is currently underfunded and must compete for supplies with bilateral government-industry supply agreements.[44] The target for 2020 was to raise USD 2 billion in initial funding for LMICs, which was met in December of that year. In 2021, additional USD 5 billion was estimated to be needed for LMICs, excluding fund for self-financing countries. COVAX was estimated to be USD 800 million short of its financial projections for the year, notwithstanding new pledges made at the G7 Leaders' Summit in February 2021. Despite this development, considerable doubts remained regarding COVAX's ability to fulfill its goal of supplying 1.8 billion doses of the COVID-19 vaccine by the end of 2021.[36,44] At present, the organization is seeking at least $3.7 billion to acquire at least 600 million of these doses for the pandemic vaccine pool, which will aid advance market commitment (AMC) countries in reducing demand and supply concerns in 2022 and beyond. At present, COVAX has a portfolio of over 2.8 billion doses that will be made accessible to AMC by mid-2022, with approximately 300 million doses for Self-Financing Participants (SFPs), based on existing financing and confirmed donations [Figure 2].

The good news is that as at March 26, 2022, more than 11.1 billion doses had been administered in 184 nations (142 shots for every 100 people) after more than a year of the world's largest vaccination program was kicked started. The most recent rate was about 21.6 million doses per day (https://www.bloomberg.com/graphics/covid-vaccine-tracker-global-distribution/). China is leading in the COVID-19 vaccination effort (over 3 billion doses), followed by India (over 1 billion doses), then EU (over 875 million doses) and US (over 558 million doses) just to mention a few. Sad to say, only about 10 out of 100 people have received the initial dose of the vaccine in Africa [Figure 3].

## COVID-19 VACCINE SUPPLY CHAIN BOTTLENECKS IN AFRICA

Vaccine disparity is not only unjust; but it is also epidemiologically incorrect, given the risk of harmful mutations that could compromise vaccine effectiveness. Africa may likely become the COVID epicenter if nothing is done to shift the narrative. The COVID-19 pandemic is already

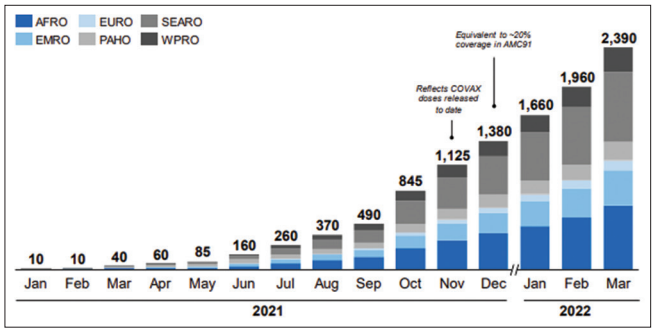


**Figure 2:** A chart showing COVAX Facility global available supply forecast by the WHO region. Source: https://www.gavi.org/sites/default/files/covid/covax/covax-supply-forecast.pdf

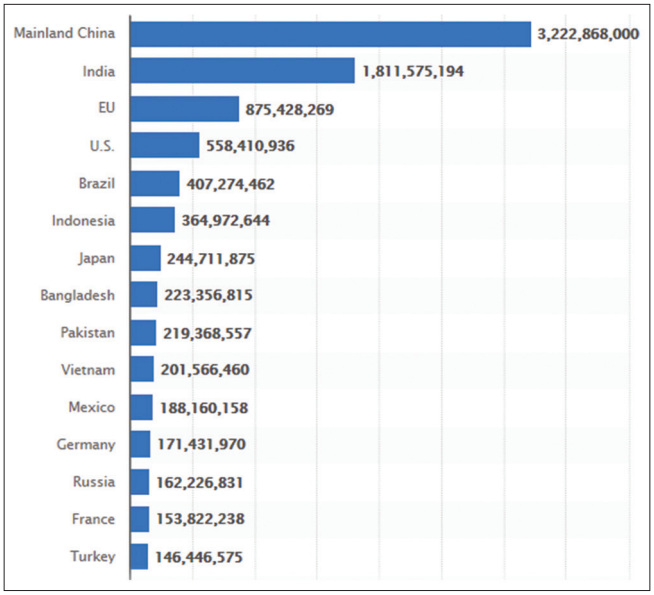


**Figure 3:** A chart showing number of COVID-19 vaccine doses administered worldwide as of March 21, 2022, by country. Source: https://www.statista.com/statistics/1194934/number-of-covid-vaccine-doses-administered-by-county-worldwide

putting a strain on Africa's health systems. Despite the fact that COVID-19 vaccines have been created, many African countries continue to confront barriers to vaccine access and availability due to high costs and technical constraints, among other factors.[46] Several bottlenecks have been identified as impeding the delivery of COVID-19 vaccination in Africa.[47]

### Inadequate funds

Many African countries have put aside special funds to cover the cost of distributing the initial batch of vaccines, including the funds to ensure that all health personnel receive the vaccines, but as the number of people to be reached grows and the areas to be covered expands beyond major cities, funding shortfalls are becoming more of a major concern. A shortage of funds is already causing delays in many African countries, in addition to a lack of vaccinators, sub-optimal training, poor communication to increase vaccine uptake, and an inability to acquire essential data or print and distribute immunization cards. Interestingly COVAX partners have pledged to giving up to 30% of Africa's vaccine doses for free, but African governments must fund vaccines for the remaining individuals they want to vaccinate, as well as invest in the mechanisms they will need to do it. According to the World Bank, Africa still requires roughly 12 billion US dollars to reach enough people to achieve adequate COVID-19 protection.[46]

### Lack of technical-know-how

Most African countries lack the technological resources needed to research and manufacture vaccines. In Africa, only few research laboratories with foreign support have the technical capacity to design and manufacture COVID-19 vaccines.

### Conspiracy theories and vaccine hesitancy

Several African governments have postponed or stopped vaccination rollouts due to safety concerns. Many of these fears were fanned by reports of serious adverse effects in the United States of America and Europe. The suspension of the AstraZeneca vaccination among younger people in Europe had a negative impact on vaccine uptake among younger health professionals in various African nations. Concerns about the safety and efficacy of COVID-19 vaccines are spreading too quickly on social media, as are disinformation and misinformation resulting in widespread increase in vaccine anxiety and hesitancy. Worst still, many African countries have little capacity to track and report adverse reactions to vaccination, as well as investigate significant adverse events and disseminate fact-based information about the benefits and hazards to their populations.[10]

### Slow rollout

So far, COVID-19 vaccine rollouts have been outstanding in some African countries, and eight African countries have already used all of their COVAX doses. Despite this, nine countries have supplied less than a quarter of their doses, and 15 have used less than half of their doses. Delays are caused by a lack of funding, skilled professionals, and public apprehension about receiving the vaccine. In some nations, the implementation is being slowed due to insufficient planning, which

includes focusing on priority groups and remote populations.[36]

### Difficulty in reaching the highest priority groups

In hospitals and clinics, health personnel are easy to find, but older persons and those with diseases that put them at higher risk of COVID-19 are not always easy to access, especially in rural regions. Some African countries, such as Angola, Ghana, and Nigeria, used community mobilizers to go door-to-door to register priority groups in advance before the arrival of vaccines. Yet, in many African countries, authorities lacked complete and accurate documentation of people's whereabouts, ages, and up-to-date information on which persons had pre-existing ailments, as well as the means to list them all ahead of time. For these reasons, and to avoid wasting vaccines, a portion of the doses were used in a number of African countries to vaccinate persons who were not in the top priority groups.[36]

### Disruptions to essential health services due to the pandemic

Throughout the pandemic and the introduction of COVID-19 immunizations, over a third of African countries have reported disruptions in key health and immunization services. The main driver of the disruptions, according to two-thirds of these countries, was the reallocation of staff to give COVID-19 relief, but fear of contracting COVID-19 has also led to a decrease in the number of patients seeking care for other ailments. To deal with the pandemic, 15 African countries postponed measles vaccination campaigns until 2020. While interruptions to other immunization programs appear to be reducing, they remain a danger.[36,37]

Despite the fact that immunization initiatives are gaining pace in many developed countries, there are still significant gaps in vaccine access around the world. So many countries are yet to receive the single dose of the vaccine. Only about 14.4% of the population in resource limited countries have receive a single dose. According to Africa CDC, as at March 23, 2022, a total of 489.6 million doses of the COVID-19 vaccines (AstraZeneca, BioNTech, Johnson and Johnson, Moderna and Sinovac) have been supplied to 51 African countries by COVAX. The top three African countries with the highest vaccine supply are Egypt (92,166,020), followed by Nigeria (68,086,973) and Morocco **(**60,556,490) with immunization coverage of 52.63%, 20.43%, and 82.46%, respectively [Figure 4]. Sadly to say, only 1.23% of the vaccinated African population has received the booster dose.[47]

## IMPLICATIONS OF COVID-19 VACCINE SUPPLY CHAIN BOTTLENECKS IN AFRICA

The existence of the bottlenecks in the African COVID-19 vaccine supply chain discussed above implies that enough doses will not be readily and evenly made available in a timely manner to the unvaccinated and to those who are in need of booster doses haven received the initial dose of the vaccine.[22,48] Delay between doses might result in the development of partial immunity among the many millions people already vaccinated and worst still, create a potential breeding ground for vaccine-resistant variants.[24] Getting everyone vaccinated with a single dose with no doses available for a timely boost may not be without virological and immunological consequences, especially in resource-constrained countries in Sub-Sahara Africa with a shaky health system and numerous supply chain bottlenecks.[10,17] Two major implications associated with delay in administering booster doses of the COVID-19 vaccine have been identified and are discussed below: Virological and immunological.

## VIROLOGICAL IMPLICATIONS

Coronaviruses, by their very nature, are prone to mutation, and they do so, on a regular basis (at least every 14 days). As the pandemic spreads, a unique environment emerges, with unfathomable billions of viral replications taking place every second, allowing mutations to emerge as copying errors occur during viral assembly. Several

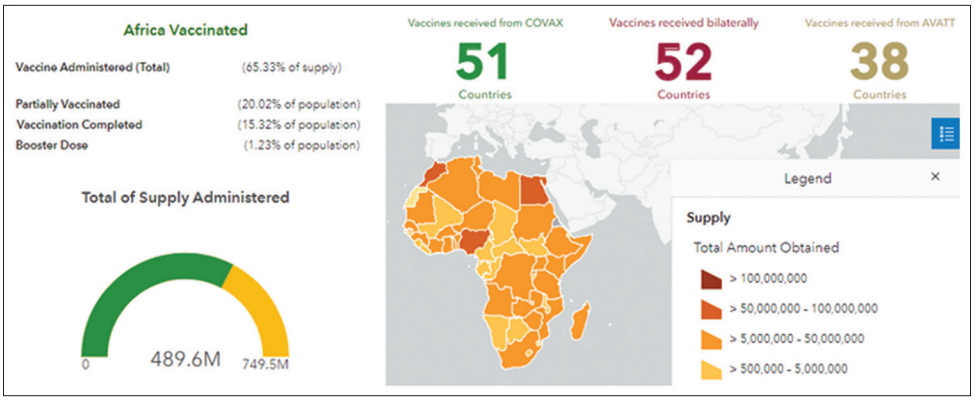


**Figure 4:** A map showing COVID-19 vaccine supply and coverage in Africa as at March 23, 2022. Source: https://africacdc.org/covid-19-vaccination

countries, including the United States, France, the Netherlands, and Denmark, have discovered a new COVID-19 variant (Deltacron), which is a mix Delta and Omicron. Viral mutations have been shown to interfere with the effectiveness of antibodies used to treat COVID-19, prompting worries that they could also interfere with vaccine-induced antibodies. Mutations reduce the ability of antibodies from some recovered COVID-19 patients to neutralize viruses expressing the coronavirus spike protein by a factor of ten or more, according to Browne.[49] Virologists are concerned that increasing the dose interval from 3 weeks to 3 months could hasten the creation of such mutants by generating a pool of sub-immune persons with enough antibodies to delay the virus and prevent symptoms, but not enough to eradicate it. Those persons could incubate viruses with mutations that allow them to avoid vaccine-induced antibodies, such as altering the amino acid sequence at a place where antibodies used to bind, preventing the virus from penetrating cells and reproducing. Because most COVID-19 vaccines only elicit immunity to one protein, the spike protein on the virus's surface, mutated viruses may be able to resist the new vaccines more easily than vaccines that elicit broader immunity.[16,17]

Interestingly, vaccine manufacturers can upgrade vaccines if SARS-COV-2 mutates dramatically over time. According to records, Pfizer and Moderna's mRNA vaccines are ideally adapted to upgrades. A novel vaccine can be made in 6 weeks using the available vaccine platforms. As a result, developing a new vaccine to combat the new variant should not be a big deal.[22,49]

## IMMUNOLOGICAL IMPLICATIONS

Given the severity of COVID-19, partial immunization is as good as no immunity at all, especially in the immunocompromised and elderly. Because re-infection has been documented in COVID-19 patients, this indicates that antibodies developed against SARS-CoV-2 are not long lasting even among vaccines, necessitating the administration of booster doses as soon as possible.[4,50]

Because no COVID-19 vaccine is 100% effective, some infections in vaccinated people are to be expected, and the risk of breakthrough infection is increased with certain variants such as Delta and Omicron. Despite this, the risk of severe breakthrough infection with the Delta variant is still very low, and preliminary research suggests that the same is true for Omicron, especially among those who had a booster immunization. Infection following vaccination is far less likely to produce serious disease than infection in people who have not been immunized. The rates of serious sickness and death owing to breakthrough COVID-19 were 1.5 and 0.3 per 10,000, respectively, in a study of nearly 1 million vaccinated members of a large health system in the United States. Older age (>65 years) and various comorbidities are both risk factors for poor outcomes in unvaccinated people.[4,26]

Another immunological implication is that postponing booster doses will have a deleterious influence on herd immunity. This is because the existence of insufficient numbers of individuals with full protection increases the probability of infection among susceptible individuals in a group. Individuals who have been fully immunized usually

act as a protective barrier for those who have not been immunized or have only been partially immunized. The absence of herd immunity in a population results in substantial increases in disease incidence. The level of immunity required for this indirect protective effect is usually determined by a number of parameters, including the virus's transmissibility, the form of vaccine-induced immunity, and the geographic distribution of the immunized persons.[10]

## WAY FORWARD

Going forward, in light of the face of vaccine disparity, on the one hand, and the necessity for widespread delivery of booster doses in a timely way, on the other hand, the following measures are hereby recommended:

- Vaccine-producing countries must continue to expand their production capacity and supply;
- Governments of such countries must remain willing to share surplus vaccine with COVAX in order to reach the most vulnerable regions of the world.[23]
- The World Health Organization (WHO) must continue to assist African countries by developing long-term strategies that include binding commitments to make vaccines available where they are most needed, such as expanding licensing arrangements to accelerate production, and coordinated approaches to sharing intellectual property (IP) and technology.
- COVAX in particular should also collaborate with the African Vaccine Acquisition Task Team (AVATT), which has pooled fund to acquire vaccines for its member states, to ensure the best allocation and distribution of vaccines.
- African countries must continue to expand the supply logistics and take immediate steps to improve vaccination campaign capability.[37]
- Still, the African countries must develop and continue to develop local capacity for production of indigenous vaccine to augment the global demand.[51]
- They must leverage on the mRNA technology transfer center established in South Africa this year (2022) by the WHO to assist vaccine makers on the continent. The goal of the vaccine hub is to ensure that vaccine manufacturers in African countries have the technical know-how to mass-produce mRNA vaccines in accordance with international standards. The benefits of this program are expected to extend far beyond COVID19, by providing a platform for vaccines against other illnesses ravaging Africa, such as HIV, malaria, and tuberculosis.[52,53]
- Finally, charity cannot guarantee continued global access to vaccines. African countries must be committed to an organized systems that are long-term sustainable and provide necessary safety net to ensure that vaccines are produced and provided where they are most needed in a timely manner.

## CONCLUSION

So far, it is now very clear that the problem is not just one of supply; but also that of unfair distribution. The current global health crisis is the ultimate test of our moral solidarity and unity. However, the remedy is not charity: Due to the emergence and spread of variants, the pandemic will not be gone until it is over worldwide. Africa cannot and must not be ignored when it comes to vaccination. Governments should act now, regardless of international borders, to take ownership and scale up production, speed up vaccination by reallocating supplies to areas with the highest need, and ensure that the necessary logistics required for their distribution are in place; provide COVAX with additional financial support; and formulate long-term strategies that include commitments to make vaccines available where they are most needed, including through technological transfer and intellectual property exchange. By all means, booster doses must be made available in a timely manner in order to leverage the full potential of the existing COVID-19 immunization programs as part of a concerted effort to win the war against the coronavirus. All these and many more will give unwavering hope of survival to the African people.

## COMPETING INTERESTS

The authors have declared that no competing interests exist.

## FUNDING

This compilation is a review article written by its authors and required no substantial funding to be stated.

## REFERENCES

1. Myerson H. Vaccine Equity: What, How, and When? Concern Worldwide US; 2022. Available from: https://www.concernusa.org/story/vaccine-equity-explained [Last accessed on 2022 Jan 28].
2. World Health Organization. COVID-19; 2022a. Available from: https://www.covid19.who.int [Last accessed on 2022 Mar 24].
3. Edwards KM, Orenstein WA. COVID-19: Vaccines; 2022. Available from: https://www.uptodate.com/contents/covid-19-vaccines? [Last accessed on 2022 Mar 20].
4. Jeyanathan M, Afkhami S, Smaill F, Miller MS, Lichty BD, Xing Z, *et al*. Immunological considerations for COVID-19 vaccine strategies. Nat Rev Immunol 2020;20:615-32.
5. Burckhardt RM, Dennehy JJ, Leo LM, Poon LJ, Lynn WE. Are COVID-19 vaccine boosters needed? The science behind boosters. J Virol 2022;96:e01973-21.
6. Madad S, Jetelina K. Positive Impact of COVID19 Vaccines at the Individual and Population Level. Belfer Center for Science and International Affairs, Harvard Kennedy School; 2021. Available from: https://www.belfercenter.org/publication/positive-impact-ozid19-vaccines-individual-and-population-level [Last accessed on 2022 May 20].
7. Centers for Disease Control and Prevention (CDC). COVID-19 Vaccine Booster Shots. 2022a. Available from: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/booster-shot.html [Last accessed on 2022 Mar 24].
8. Centers for Disease Control and Prevention (CDC). CDC Recommends Additional Boosters for Certain Individual; 2022b. Available from: https://www.cdc.gov/media/releases/2022/s0328-covid-19-boosters.html [Last accessed on 2022 Mar 29].
9. Bown C, de Bolle M, Obstfeld M. The Pandemic is not Under Control Anywhere Unless it is Controlled Everywhere, Peterson Institute for International Economics; 2021. Available from: https://www.piie.com/blogs/realtime-economic-issues-watch/pandemic-not-under-control-anywhere-unless-it-controlled [Last accessed on 2021 Mar 05].
10. Enitan SS, Oyekale AO, Akele RY, Olawuyi KA, Olabisi EO, Nwankiti AJ, *et al*. Assessment of knowledge, perception and readiness of Nigerians to participate in the COVID-19 vaccine trial. Int J Vaccines Immun 2020a;4:123.
11. Amanat F. In Depth Characterization of Immune Response against the Spike Protein of Sars-Cov-2 in Response to Infection and mRNA Vaccination. Icahn School of Medicine at Mount SinaiProQuest Dissertations Publishing; 2021. Available from: https://www.proquest.com/docview/2572610011 [Last accessed on 2022 Feb 05].
12. Borges V, Isidro J, Cunha M, Cochicho D, Martins L, Banha L, *et al*. Long-term evolution of SARS-CoV-2 in an immunocompromised patient with non-Hodgkin lymphoma. Msphere 2021;6:e00244-21.
13. All Africa. WHO Interim Statement on Covid-19 Vaccine Booster Doses; 2021. Available from: https://www.allafrica.com/stories/202108110044.html?cv=1 [Last accessed on 2022 May 17].
14. World Health Organization. Interim Statement on Booster Doses for COVID-19 Vaccination. Available from: https://www.who.int/news/item/04-10-2021-interim-statement-on-booster-doses-for-covid-19-vaccination [Last accessed on 2022 Jan 25].
15. World Health Organization. COVID-19: Booster Shots. Episode #53. Geneva: World Health Organization; 2022. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/media-resources/science-in-5/episode-53---covid-19-booster-shots? [Last accessed on 2021 Sep 21].
16. Davido B, Davido G, Annane D. No further delays in offering booster doses in countries experiencing a major resurgence of COVID-19. J Travel Med 2021;28:187.
17. Wadman M. Could Too Much Time between Doses Drive the Coronavirus to Outwit Vaccines? 2021. Available from: https://www.sciencemag.org/news/2021/01/could-too-much-time-between-doses-drive-coronavirus-outwit-vaccines [Last accessed on 2021 Jan 16].
18. Kupferschmidt K. COVID-19: New mutations raise specter of immune escape. Science 2021;371:329-30.
19. Centers of Disease Control and Prevention (CDC). Implications of Emerging SARSCoV-2 Variant; 2020. Available from: https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-emerging-variant.html [Last accessed on 2022 Jan 14].
20. Enitan SS, Ihongbe JC, Oluremi AS, Mensah-Agyei GO, Adetiloro EO, Akele RY, *et al*. Emergence of new variants of SARS-CoV-2: Current scenario, potential consequences and future direction. Ann Microbiol Infect Dis 2020;3:4-9.
21. Enitan SS, Effiong EJ, Junaid SA, Ohanu EC, Itodo GE, Adekunbi OA, *et al*. Public health concerns of SARS-CoV-2 omicron variant: What we know so far! J Virol Res Rep 2022;3:1-4.
22. Antal C, Cioara T, Antal M, Anghel I. Blockchain platform for COVID-19 vaccine supply management. IEEE Open J Comput Soc 2021;2:164-78.
23. Cohen J. Countries now scrambling for COVID-19 vaccines may soon have surpluses to donate. Science 2021; Available from: https://www.scienceopen.com/document?vid=db84d1cc-3aed-400c-8307-03b3c2a315eb [Last accessed on 2022 Jan 30].
24. Economist Intelligence Unit. Coronavirus Vaccines: Expect Delays Q1 Global Forecast. London: Economist Intelligence Unit; 2021. Available from: https://www.eiu.com/n/campaigns/q1-global-forecast-2021/ [Last

accessed on 2022 Feb 15]
25. Maragakis L, Kelen GD. Booster Shots, Third Doses and Additional Doses for COVID-19 Vaccines-What You Need to Know; 2022. Available from: https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/booster-shots-and-third-doses-for-covid19-vaccines-what-you-need-to-know [Last accessed on 2022 Feb 02].
26. Nixon DF, Schwartz RE, Ndhlovu LC. Booster vaccines for COVID-19 vaccine breakthrough cases? Lancet 2022;399:1224.
27. Stiepan D. Study Confirms Effectiveness of COVID-19 Booster Vaccinations; 2022. Available from: https://www.newsnetwork.mayoclinic.org/discussion/study-confirms-effectiveness-of-covid-19-booster-vaccinations [Last accessed on 2022 Feb 10].
28. Missouri Department of Health and Senior Services (MDHSS). Moderna and J&J COVID-19 Booster Shots Now Being Administered to Eligible Missourians; 2021a. Available from: https://www.health.mo.gov/news/newsitem/uuid/405ac93f-a325-4347-813e-13083b82bae9 [Last accessed on 2022 Jan 28].
29. Archyworldys. Booster Dose of Pfizer Vaccine Restores 95% Immunity, Analysis Reveals; 2021. Available from: https://www.archyworldys.com/booster-dose-of-pfizer-vaccine-restores-95-immunity-analysis-reveals [Last accessed on 2022 Jan 28].
30. Missouri Department of Health and Senior Services (MDHSS). Pfizer COVID-19 Booster Shots Now Being Administered to Eligible Missourians; 2021b. Available from: https://www.health.mo.gov/news/newsitem/uuid/547d16b8-72a3-47c9-8176-8c227c3f7343 [Last accessed on 2022 Feb 08].
31. GAVI. COVID-19 Vaccine Boosters: Is a Third Dose Really Needed? 2022a. Available from: https://www.gavi.org/vaccineswork/covid-19-vaccine-boosters-third-dose-really-needed?gclid=EAIaIQobChMIkOST0JnD9gIVCJ7VCh2-zg0mEAAYASAAEgKJpvD_BwE [Last accessed on 2022 Feb 23].
32. Krause PR, Fleming TR, Peto R, Longini IM, Figueroa JP, Jonathan AC, *et al*. Considerations in boosting COVID-19 vaccine immune responses. Lancet 2021;398:1377-80.
33. The Guardian. Coronavirus: What is the Deltacron Variant of COVID and where has it Been Found? 2021a. Available from: https://www.theguardian.com/world/2022/mar/11/what-is-deltacron-covid-variant-uk?msclkid=2e69f53aad5411ec885da6b42623d33f [Last accessed on 2022 Mar 15].
34. Savage M. New COVID Variants "Would Set us Back a Year", Experts Warn UK Government; 2021b. Available from: https://www.theguardian.com/world/2021/aug/15/new-covid-variants-will-set-us-back-a-year-experts-warn-uk-government?msclkid=2e698fc8ad5411ecbdd54c796aa89f50 [Last accessed on 2022 Mar 01].
35. GAVI. Principles for Sharing COVID-19 Vaccine Doses with COVAX. 2021b. Available from: https://www.gavi.org/sites/default/files/covid/covax/COVAX_Principles-COVID-19-Vaccine-Doses-COVAX.pdf [Last accessed on 2022 Mar 01].
36. Sidibé M. Vaccine Inequity: Ensuring Africa is Not Left Out. Brookings; 2022. Available from: https://www.brookings.edu/blog/africa-in-focus/2022/01/24/vaccine-inequity-ensuring-africa-is-not-left-out [Last accessed on 2022 Feb 16].
37. Du L, Wang M, Raposo VL. International efforts and next steps to advance COVID-19 vaccines research and production in low- and middle-income countries. Vaccines 2022;10:42.
38. Winiarek CW. The Politics of Medicine: Power, Actors, and Ideas in the Making of Health. Winiarek, Claire Wulf. Old Dominion UniversityProQuest Dissertations Publishing; 2021. Available from: https://www.proquest.com/docview/2583438788 [Last accessed on 2022 Jan 11].
39. Anthony DS, Joshua W. Reserving coronavirus disease 2019 vaccines for global access: cross sectional analysis. BMJ 2020;371:m4750.
40. Schwartz JL. Equitable global access to coronavirus disease 2019 vaccines. BMJ 2020;371:m4735.
41. Mohanty S. COVID-19 Vaccine: Global Supply Chain Challenges. Amity Research Centers, Case Reference no. 321-0106-1; 2021. Available from: https://www.thecasecentre.org/products/view?id=175765 [Last accessed on 2022 Jan 20].
42. Feng S, Phillips DJ, White T, Sayal H, Aley PK, Bibi S, *et al.* Correlates of protection against symptomatic and asymptomatic SARS-CoV-2 infection. Nat Med 2021;27:2032-40.
43. Bergwerk M, Gonen T, Lustig Y, Amit S, Lipsitch M, Cohen C, *et al*. Covid-19 breakthrough infections in vaccinated health care workers. N Engl J Med 2021;385:1629-30.
44. Organization for Economic Co-operation and Development (OECD). Access to COVID-19 Vaccines: Global Approaches in a Global Crisis; 2021. Available from: https://www.oecd.org/coronavirus/policy-responses/access-to-covid-19-vaccines-global-approaches-in-a-global-crisis-c6a18370 [Last accessed on 2022 Jan 27].
45. Brosig M. COVID-19 and Global Order. In: Africa in a Changing Global Order. Ch. 6. Cham: Palgrave Macmillan; 2021. p. 171-209.
46. Lucero-Prisno DE 3rd, Ogunkola IO, Imo UF, Adebisi YA. Who will pay for the COVID-19 vaccines for Africa? Am J Trop Med Hyg 2021;104:794.
47. African Centers for Disease Control and Prevention (ACDC) (2022). Africa CDC Vaccine Dashboard. Available from: https://www.africacdc.org/covid-19-vaccination [Last accessed on 2022 Feb 13].
48. Linkov I, Keenan JM, Trump BD. COVID-19: Systemic Risk and Resilience. Berlin, Germany: Springer Science and Business Media LLC; 2021. Available from: https://www.scienceopen.com/book?vid=dc4ecef7-e82c-4f50-b666-7ac8d1b969f1 [Last accessed on 2022 Feb 05].
49. Browne ED. Deltacron COVID Variant, Mix of Delta

and Omicron, Found in at Least Four Countries. News Week: Tech and Science; 2022. Available from: https://www.newsweek.com/deltacron-covid-variant-omicron-delta-found-countries-1687154?cv=1
50. Sadarangani M, Marchant A, Kollmann TR. Immunological mechanisms of vaccine-induced protection against COVID-19 in humans. Nat Rev Immunol 2021;21:475-84.
51. Nkengasong JN, Ndembi N, Tshangela A, Raji T. COVID-19 vaccines: How to ensure Africa has access. Nature 2020;586:197-9.
52. Ewodage R. Nigeria, Five Other African Countries to Begin Production of COVID-19 Vaccines-WHO. Channels TV Agency Report; 2022. Available from: https://www.channelstv.com/2022/02/18/nigeria-five-other-african-countries-to-begin-covid-vaccine-production-who [Last accessed on 2022 Feb 20].
53. Ileyemi M. COVID-19: Nigeria, Five Other African Countries Get WHO Approval for Vaccine Production. Premium Times Nigeria News; 2022. Available from: https://www.premiumtimesng.com/news/more-news/512356-covid-19-nigeria-five-other-african-countries-get-who-approval-for-vaccine-production.html [Last accessed on 2022 Feb 20].