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The Africa COVID-19 legacy—Improved vaccinology for pandemic preparedness

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The COVID-19 pandemic caused global disruption that reverberated across Africa and revealed deep systemic vulnerabilities. Nonetheless, the scientific response to SARS-CoV-2 catalyzed unprecedented global scientific collaboration, established new collaborative networks, and accelerated local capacity building across Africa. This legacy extends beyond COVID-19, informing responses to subsequent mpox and Ebola outbreaks, and establishes a framework to respond to future infectious disease threats in Africa.

Introduction

The rapid development of vaccines in response to the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) that causes the disease known as COVID-19 will be remembered as a remarkable achievement in medical and scientific history. The global scientific community's rapid identification of SARS-CoV-2 in December 2019, the sharing of its genetic sequence, and the subsequent development and distribution of vaccines was extraordinary. Nevertheless, the COVID-19 pandemic also revealed deep inequities and exposed critical weaknesses in existing systems, particularly in under-resourced settings. From an African perspective, the pandemic's impact went far beyond health outcomes, encompassing fundamental economic changes from which the continent is still recovering. This impact was especially pronounced given Africa's existing structural challenges that were exacerbated during "lockdowns," including food insecurity, limited health infrastructure, and high levels of informal employment. Nevertheless, Africa's response to SARS-CoV-2 sparked an extraordinary level of cross-continental scientific collaboration, fostering new partnerships and accelerating the development of local expertise. Although significant challenges remain for pandemic preparedness across Africa, the scientific advances brokered during the COVID-19 pandemic provided a foundation for managing future infectious disease threats and has already shaped African-led responses to subsequent mpox and Ebola outbreaks.

Recent virological outbreaks in Africa with pandemic risk

In the first half of 2025, several virological outbreaks in Africa highlighted the continent's vulnerability to emerging and re-emerging infectious diseases. The most widespread was the mpox virus outbreak, which affected more than 15 African countries, with the Democratic Republic of Congo and Uganda reporting the highest numbers of cases. By early 2025, more than 100,000 suspected cases of mpox and nearly 23,000 confirmed cases had been recorded, prompting the Africa Centres for Disease Control and Prevention (Africa CDC) to declare the mpox outbreak as a Public Health Emergency of Continental Security (PHECS). South Africa recorded its first clade Ib-associated mpox cases, underscoring the cross-border nature of the outbreak. Uganda faced an Ebola (Sudan virus) outbreak from January 2025 to April 2025, reporting 14 probable or confirmed cases and four deaths, before successfully ending the outbreak after 87 days of careful monitoring. Tanzania faced a Marburg virus outbreak in January 2025, with two confirmed and eight probable fatal cases, but managed to contain the outbreak within two months. In addition, chikungunya resurfaced in the Indian Ocean region, including Mauritius, Mayotte, Reunion, and Somalia, raising concerns about the spread of mosquito-borne viruses.

The sporadic virus outbreaks, along with ongoing documentation of measles in several African countries, highlight the need for robust surveillance, rapid response, and international cooperation to mitigate the consequences thereof. The risk of major outbreaks of viral disease in Africa is likely to be exacerbated because of climate change and changing distribution profiles of vectors and associated pathogens.

Post COVID-19, global and continental public health policy shifts such as the establishment by Africa CDC of the PHECS framework enables rapid, coordinated continental action in response to health threats. The PHECS framework is further supported by the World Health Assembly amendments to the International Health Regulations (IHR 2005), introducing the explicit term "pandemic emergency" in mid-2024. There are, however, significant gaps in the value chain from basic research to vaccine delivery in Africa, highlighting the ongoing challenges

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in building resilient pandemic preparedness systems. The research challenges in Africa are compounded by recent reduction in the global funding landscape, which further threaten the sustainability of already fragile African research networks.

Retention of African-led South-South initiatives

South-South networks have been strengthened by emergency investments made by African governments and international funders during the pandemic that spanned genomic surveillance systems, basic immunological capacity, clinical research, and vaccine development pathways. In South Africa, next-generation sequencing-South Africa (NGS-SA)[1] leveraged investments made in sequencing for HIV surveillance of antiretroviral drug resistance to rapidly respond to the SARS-CoV-2 pandemic. The consortium made essential contributions to the global COVID-19 response, identifying the Beta and Omicron variants of concern.[2,3] In addition, initiatives to refine wastewater-based surveillance as a method to detect the emergence and spread of local SARS-CoV-2 infections were developed in South Africa,[4] which has subsequently been expanded for surveillance of other infectious diseases such as measles and HIV.

Similarly, the Africa Pathogen Genomics Initiative (Africa PGI) emerged as a flagship Africa CDC initiative to build and strengthen molecular diagnostics, genomic surveillance, and epidemiology ecosystems across the continent.[5] Africa PGI 2.0 builds on this progress, to build a skilled workforce for molecular diagnostic, pathogen genomics, and bioinformatics, integrated genomic surveillance to strengthen early warning systems, and facilitate timely sharing of high-quality genomic data. The genomics initiative represents a fundamental shift from dependence on external technical assistance to building African capacity for pathogen surveillance and analysis. This capacity proved crucial not only for the COVID-19 response but also for addressing subsequent outbreaks and emerging infectious disease threats.[5]

South-South networks of immunologists that systematically leveraged connections to sequencing hubs have made important scientific discoveries. One such network is the Global Immunology and Immune Sequencing for Epidemic Response (GIISER) network, which was founded by the Gates Foundation in 2021 in the wake of the pandemic. By uniting expertise and resources from Africa, Asia, and South America, GIISER established a robust platform integrating genomic surveillance, immunology, and capacity development. This collaborative approach enabled the rapid immunological profiling of new SARS-CoV-2 variants, such as Beta and Omicron, defined the risk of pathogen diversification in immunocompromised people living with HIV, isolated monoclonal antibodies, profiled population immunity, and made key contributions to evaluating COVID-19 vaccine effectiveness. Through sharing technology, standardized protocols, and coordinated training across continents, this network of immunologists generated over 50 publications and trained over 90 staff and students in advanced immunological techniques.[6] GIISER's efforts informed public health policies, accelerated the discovery of monoclonal antibodies, and empowered local scientists and institutions, strengthening their ability to respond to infectious disease threats. GIISER's achievements highlight the importance of sustaining and expanding regional networks in the era of declining research funding. To sustain these networks, diversification of research and funding streams is necessary, and networks need to transition out of "emergency mode." Indeed, the GIISER network has sourced funding from other funders to pursue research into mpox, Lassa fever, Ebola, Marburg virus disease, Rift Valley fever, Nipah virus disease, Crimean-Congo hemorrhagic fever, respiratory syncytial virus, and bat coronaviruses.

Expanding discovery, development, and access to monoclonal antibodies against infectious diseases

The COVID-19 pandemic resulted in increasing recognition of the advantages and disadvantages of monoclonal antibodies (mAbs) for combating threats like pandemics. mAbs are transformative therapies for cancer, autoimmune diseases, and infectious diseases. Though their utility against highly mutable pathogens may be short lived, global advances in antibody engineering are now being further driven by machine learning and artificial intelligence.

Africa is still significantly disadvantaged in accessing and manufacturing capacity of mAbs compared with high-income regions. Despite representing about 20% of the world's population, less than 1% of global mAb sales occur in Africa. Although the capacity for mAb discovery has increased in Africa, this progress is not effectively translating into therapeutics and diagnostics. Technologies such as rapid assembly, transfection, and production of immunoglobulins from single-sorted B cells have the potential to be transformational in outbreak settings. This platform accelerates mAb isolation, enabling scientists to rapidly isolate and characterize antibodies for use as diagnostics or emergency prevention and treatment tools. Although the upstream research platforms have been implemented at multiple sites (e.g., through the ADVANCE [Accelerate the Development of Vaccines and New Technologies to Combat the AIDS Epidemic] and GIISER networks), the production of mAbs on a large scale in Africa is a key gap that must be addressed.

Currently, all mAbs used in Africa are imported, primarily from India, China, Europe, and the US. Several pilot facilities in Africa are exploring mAb manufacturing, including a new facility in Rwanda that plans to produce drugs such as trastuzumab (Herceptin) for breast cancer and aflibercept for diabetic macular edema.[7] South Africa has also initiated pilot programs and research on plant-based mAb production. The Council for Scientific and Industrial Research is developing prototypes and planning a pilot production facility for investigational use. Similarly, a consortium of scientists, clinicians, and veterinarians are exploring the use of the *Thermothelomyces heterothallica* (C-1) fungal platform to scale up mAb production.

Diagnostic and health systems strengthening

Although initial narratives suggested that Africa was spared the worst effects of the pandemic, African scientists and clinicians have long challenged this notion, given the multimorbidity of the populations.[8] Modeling indicates that many African countries experienced mortality rates similar to those of other regions. The discrepancy between official documented COVID-19 cases and the actual

impact of the pandemic stems primarily from the challenges of data collection and reporting infrastructure in African countries. Even before the COVID-19 pandemic disrupted public health surveillance systems, there was considerable variation among African countries in their ability to reliably measure and report all-cause deaths. During the COVID-19 pandemic, this variability in tracking of deaths, coupled with severely limited capacity for testing for SARS-CoV-2, led to systematic underestimation in quantifying the number of COVID-19 deaths, infection fatality risks, and excess deaths across the continent.[9] In South Africa, despite having the most advanced SARS-CoV-2 diagnostics in Africa, the number of excess deaths from natural causes during 2020 and 2021 exceeded confirmed COVID-19 deaths by 3-fold. The strong temporal correlation between excess deaths and reported COVID-19 deaths indicates that the majority of excess deaths during this period were associated with COVID-19 in South Africa. Many African countries found it difficult to estimate excess deaths, or to identify and report COVID-19 deaths accurately, demonstrating the value of near-real-time monitoring of mortality through the use and demographic analysis of data obtained from the country's National Population Register.[10]

Testing capacity for SARS-CoV-2 was a critical bottleneck in African countries, with marked differences in testing rates ranging from 723 people per 1,000 population in Botswana to 11 per 1,000 in Madagascar.[9] This disparity in testing infrastructure affected the immediate pandemic response and undermined the ability to accurately assess the scope and impact of the pandemic. In terms of diagnostics, at least one rapid SARS-CoV-2 antigen test was fully developed and manufactured in Africa, and other nations participated in the adaptation, validation, and rollout of various rapid tests. Nevertheless, most of the rapid COVID-19 tests used across the continent were imported or developed through international collaboration. Local efforts focused on validation, evaluation, and manufacturing scale-up. One way to address this for future outbreaks is to refine the ecosystem to enable the rapid import, validation, and approval of internationally developed tests. However, Africa also needs increased capabilities for developing rapid diagnostic tests for pathogens of particular relevance to its context, from antigen/antibody discovery to deployment. Currently, mpox is primarily detected on the African continent through molecular diagnostic testing, was designed to detect clades I and II, which is crucial since both are currently circulating in Africa. Currently, rapid diagnostic tests (RDTs) are not recommended for mpox detection in Africa due to the low clinical sensitivity of existing tests. Some progress is being made toward local diagnostic manufacturing, including a PCR-assay in Morocco that demonstrated high sensitivity and specificity in Africa CDC evaluations. An mpox rapid antigen test is also being evaluated in Kenya. Similarly, there are gaps in Ebola diagnostics. Rapid diagnostics tests for Ebola viruses cannot distinguish between different species of the virus. Although several RDTs can detect multiple Ebola species, they do not provide species identification (Zaire, Sudan, or Bundibugyo), and others only reliably detect Zaire Ebola viruses. Mortality rates vary greatly between species (Zaire consistently shows the highest rates of 60%–90% across outbreaks, while Bundibugyo demonstrates substantially lower rates of 37%). Therapeutic and vaccine effectiveness also vary by species. In both Ebola and mpox, the availability of clinical material from previous outbreaks in African repositories and the proven capacity for mAb isolation may enable the development of more such diagnostics in Africa.

Vaccine development and licensure

The paucity of vaccine production capability in Africa represents perhaps the largest ongoing threat to health security on the continent. Despite consuming approximately 25% of the world's vaccines, Africa produces only 1% of those administered on the continent. The continent has fewer than ten manufacturers with vaccine production capacity, primarily located in Egypt, Morocco, Senegal, South Africa, and Tunisia. Despite a flurry of funding and "hype" during the pandemic, expansion has been slow. For instance, the establishment of the mRNA Technology Transfer Program was celebrated as a significant innovation in global health equity and technology access. The program aimed to promote equitable access to mRNA vaccines by expanding sustainable manufacturing capacity in low- and middle-income countries.[11] Recently, the African Union's Partnership for African Vaccine Manufacturing announced plans to ensure that 60% of the vaccines used on the continent are produced in Africa.

To assess progress in Africa's vaccine manufacturing landscape, it is important to distinguish between true manufacturing and fill-and-finish operations. While important, fill-and-finish operations are much less complex than drug substance/active ingredient production and typically involve importing pre-manufactured antigens. Africa has substantial fill-and-finish capacity, likely to exceed 2 billion doses by 2030.[12] This capacity exceeds Africa's current vaccine demand of approximately 1.3 billion doses annually, which paradoxically risks commercial viability for manufacturers and creates sustainability challenges unless the continent can export widely.[12]

In contrast, production of drug substance/active products remains limited at 61 million doses annually, with a focus on mRNA vaccines. Three African vaccine manufacturers are expected to secure World Health Organization (WHO) prequalification for nine different vaccines by 2030.[12] This progress, albeit slow, occurs in the context of uncertain demand for vaccines manufactured in Africa at the country and continental level.[12] Manufacturing efforts across Africa should be designed to include a broad range of vaccines targeting diseases prevalent on the continent. Additionally, African governments will need to make significant investments in purchasing locally produced vaccines, even if this means paying higher prices to African manufacturers compared with what could be sourced from elsewhere.

Manufacturing is not the only bottleneck in vaccine development. Investments made during the COVD-19 pandemic significantly strengthened upstream research initiatives. Immunology research in Africa has also been bolstered by HIV research. This full value chain has resulted in the development of a locally developed and manufactured COVID-19 mRNA vaccine comparable in immunogenicity to the licensed BNT162b2 mRNA vaccine. The use of mRNA as the basis of new vaccines has increased in Africa. Afrigen in South Africa is also developing mRNA vaccines for RSV, HIV, and tuberculosis. African capabilities include mRNA and self-amplifying RNA platforms; the

development of novel, sustainable, and biorenewable lipids for delivery using lipid nanoparticle platforms; and analytics to perform preclinical assessments of encapsulation, particle sizing, delivery, toxicity, and immunogenicity. However, a key gap remains in preclinical platforms, especially non-human primate platforms. Recent US policy changes regarding research on non-human primates and animal models may shift research toward discovery medicine in human clinical trials, a strength of many African research sites. Many African laboratories have the capacity to perform basic immunogenicity testing and have served as endpoint laboratories for clinical trials, conducting validated T and B cell assays. In the HIV vaccine field, funding African labs to implement more advanced technologies has been highly effective in generating paradigm-shifting data using B cell sorting, sequencing, and bioinformatic analyses.[13] Lastly, increased capacity has been built for regulatory approval once vaccines have shown safety and efficacy in clinical trials. The African Vaccine Regulatory Forum substantially strengthened Africa's regulatory capacity for vaccine approval by institutionalizing accelerated, harmonized review processes and expanding reliance on WHO and international assessments since the COVID-19 pandemic.

HIV co-infection: An ongoing risk for pandemic prevention

Pandemic preparedness on the African continent occurs at the intersection of HIV, with 27 million people living with HIV in sub-Saharan Africa.[14] Funding cuts threaten the HIV treatment and prevention programs and risk increasing the number of immunocompromised people living with HIV. The risk of accelerated evolution of viruses resulting from zoonotic transmissions was clearly shown during the COVD-19 pandemic. It is very telling that despite African scientists contributing relatively few SARS-CoV-2 sequences in the global context, multiple highly mutated SARS-CoV-2 lineages were detected on the continent.[14] Moreover, individuals with HIV are 4–5 times more likely to contract mpox compared with those without HIV and experience significantly higher mortality.[15] Losing momentum on HIV treatment programs will not only worsen the HIV pandemic but also increase the global risk of infectious disease mutation and spread.

Conclusion

The COVID-19 pandemic fundamentally reshaped Africa's approach to managing subsequent infectious disease outbreaks, such as Ebola and mpox. This new approach leverages lessons in genomic surveillance, diagnostic capacity, and regional collaboration, while also exposing inherent systemic challenges. This continental network approach acknowledges that infectious disease threats necessitate coordinated surveillance and response capabilities that transcend national borders. The infrastructure and networks established during the SARS-CoV-2 response laid the groundwork for more coordinated, science-driven responses to emerging threats. However, gaps in equity and resource distribution persist. Ensuring the sustainability of this progress is a significant challenge, further exacerbated by funding cuts. African governments must innovate their funding models to reduce the continent's and the world's vulnerability to pandemic threats.

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DECLARATION OF INTERESTS

The authors declare no competing interests.

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