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Review Article

Lessons Learned After Two Years of Living with COVID-19: A Special Focus on Findings from Multidisciplinary Pan African Studies -

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ABSTRACT

The Coronavirus 2019 (COVID-19) has spread globally, and Africa is not excluded. The disease threatens to render millions of people poor. This current review study focuses on key areas such as its clinical features, epidemiology, genetics, spillover hosts and socio-economic impacts two years after the report of the first cases in Africa. Internet search was conducted, and scientific papers were selected using the following criteria: papers reporting on the key aspects in Africa, papers with complete information, literature review papers were excluded, papers with only abstracts were not considered, papers on other aspects which are not subject of interest were not eligible. Based on the stated criteria, 54 papers were retained. After two years of living with the pandemic, African researchers acquired some lessons. They made some recommendations for future pandemics as such: a) the experience of Africa could serve as a lesson for the global population based on its long history of living with coronaviruses and dealing with them; b) there is a need to reinforce the health care system in preparation for future pandemics of this magnitude as well as not to neglected other important existing diseases; c) the imposition of mitigation policies such as lockdown should be adapted to the local situation of each country to avoid long term consequences such as food insecurity, adolescent pregnancy, gender-based violence; c) the regions with a high diversity of bat hosts and other animal species should be regularly monitored for the emergence of novel coronaviruses, d) financial support should be made available to promote scientific research in Africa. As COVID-19 remains a priority disease, the lessons learned after two years of living with it should prepare the continent for responding holistically to future pandemics.

Keywords: COVID-19; Clinical features; Epidemiology; Genetics; Hosts; Ecomomic impact

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19), with the first case in Africa, reported on 14th February 2020, spread rapidly globally, resulting in a pandemic still ongoing in several countries. Currently, five SARS-CoV-2 Variants of Concern (VOCs) have been described in the European Union: the Alpha, Beta, Gamma, Delta, and Omicron variant of concern [1]. These variants continue to spread to other continents, including Africa. The COVID-19 burden is heterogenous globally and has been low in Africa [2,3], but its socio-economic impact has been reported to be high in the continent [4]. As of March 02, 2022, the number of confirmed COVID-19 cases in Africa was 11, 549, 076, which represented around 2.62% of the infections around the world. This pandemic seriously impacted almost all African countries' economic and social sectors, and it is threatening to render close to 58 million people poor [5]. After two years of living with the COVID-19 pandemic, it is crucial to document the lessons learned from studies conducted in Africa to get ready for future pandemics of similar magnitude.

At the start of the COVID-19 pandemic, several projects were financed to generate data to assist decision-makers to efficiently tackle the disease. One of such projects was the Pan African project entitled "African Life Story of COVID-19" (ALSO-COVID-19). The project is executed by the CAMES Health Research Topics Programme (PTR-Santé CAMES) researchers and strategic partners from CAMES countries. This ALSO-COVID-19 project was designed to provide a better understanding of the epidemiological, clinical, physiopathological, socio-cultural, economic and political determinants of COVID-19 in the African context inorder to propose an appropriate and effective response.

This current study aims at conducting a systematic review on the following topics: 1) clinical, immunological, and epidemiological aspects; 2) socio-economic impact of the disease, 3) genetic aspects and 4) spillover hosts of the virus.

MATERIALS AND METHODS

Study framework

The current review of published papers on COVID-19 from research studies conducted in Africa was realised from March 2020 to March 2022.

Literature search

Apart from the reports from the ALSO-COVID-19 project, online information was collected from electronic scholarly databases such as MEDLINE (PubMed), LitCovid, Embase (Ovid), Scopus (Elsevier), CINAHL (EBSCO), ScienceDirect (Elsevier), Web of Science (WoS), African Journal Online (AJOL) and SciELO (Web of Science).The search for unpublished studies included bioRxiv (preprints), medRxiv (preprints), and SSRN (preprints). The following initial keywords were used: "COVID-19," "SARS-CoV-2," "epidemiology," "modelling," "prevalence," "serology," "genome," "strains," "genetic," , "spillover hosts," "variants," "Africa." The inclusion criteria were papers published in Africa from March 2020 to March 2022. The exclusion criteria were: 1) review papers were not considered. Still, their references section enabled us to get relevant papers on the topic, 2) papers outside Africa with keywords of interest were not considered, 3) papers on the vaccine and mathematical modelling were not considered, 4) papers with only abstract available were not considered. Based on this exclusion criteria, 54 papers were eligible for this study.

FINDINGS AND DISCUSSION

After two years of living with COVID-19 in Africa, only few Scientists have published relevant information on its epidemiology, genetics, socio-economic impact and spillover hosts. The findings of some selected 54 studies conducted in Africa are summarised in table 1. The absence and low numbers of studies on the subject in some African countries has presented some difficulties in using locally generated findings to fight against this disease. Although COVID-19 mortality rate has been reported to be low in Africa than other continents, its impact was highly felt.

Clinical and epidemiological outcomes

COVID-19 studies focusing on the clinical, immunological and epidemiological aspects of the disease are lacking or poorly documented in most African countries [6-8]. A hospital-based study in Cameroon revealed that the most common comorbidity frequently identified among COVID-19 patients was hypertension [9]. Still, it did not predict severity [10]. Apart from hypertension, other comorbidities have already been reported to cause COVID-19 severity in patients, and they include diabetes, lung disease, HIV, Chronic Kidney Disease, and haematological disorders [11,12]. Although studies from Libya, Burkina Faso, and Guinea showed that older

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Table 1: Key findings from multidisciplinary studies on COVID-19 in Africa.

SN	Year	Author	Summary of Key findings
1	2021	Adams, et al.	This study reported that age structure of sub-Saharan Africa is the leading factor of the low morbidity and mortality of COVID-19 compared to other regions of world. Social mitigation strategies to curb its spread, such as lockdowns, have resulted in severe economic and societal consequences in terms of food security, adolescent pregnancy, gender-based violence, and disruptions in treating other diseases.
2	2022	Adjei, et al.	This study found different variants of COVID-19 in Africa.
3	2021	Amouzouvi, et al.	This study found that R0 ≤ 4 at the start of the pandemic has since fallen to R0 ~ 1.
4	2020	Asante and Mills	This study established for Ghana that socio-economic impacts of the COVID-19 pandemic in marketplaces were evident in the increased food prices, the economic hardships associated with the lockdown directive, and the forceful relocation and decongestion exercises to enforce social distancing among traders.
5	2021	Babiker	This study highlighted that the weak social determinants of health, such as poverty, inequality and multiple vulnerabilities, have aggravated the structural impact of COVID-19 on lives and livelihoods in Sudan. The absence of adequate economic and social constitutional rights (ESCR) protection in Sudan's legislative framework has therefore exacerbated the vulnerability of large sectors of the population and meant that the state lacked the legal structures and tools to respond to the pandemic
6	2021	Bouba Y, et al.	They found that diabetes prevalence, number of nurses and GHS index were found to be significantly associated with COVID-19 deaths per one million 61 population
7	2020	Bukuluki P, et al.	They found that lockdown has affected refugee livelihoods and increased income insecurity, sexual and gender-based violence and anxiety
8	2021	Basu JK, et al.	They found that COVID-positive pregnant South African women were commonly symptomatic, but incidence of adverse fetal outcomes was low. High rate of preterm labor, macerated stillbirths, and maternal deaths was a concern.
9	2021	Daw MA, et al.	This study found that older patients infected with COVID-19 were at a risk of higher disease severity and mortality. Broad geographic variability and spatio-temporal spread variation of the COVID-19 pandemic in Libya was observed.
10	2021	Delahay RJ, et al.	They highlighted the potential for exposure, onward transmission and persistence of SARS-CoV-2 in selected wild mammals (bats, canids, felids, mustelids, great apes, rodents and cervids).
11	2021	Edem B, et al.	They found that the African continent hosts considerably fewer COVID-19-related research compared to other parts of the world. This may have implications on scientific evidence available for implementing COVID-19 control efforts.
12	2021	Forbes KM, et al.	They reported that comprehensive systems for early detection and containment of wildlife virus spillover and emergence remain one of our strongest responses against the threat posed by zoonotic viruses including COVID-19.
13	2021	Fouda Mbarga N, et al.	They found in Cameroon that age (40-70), male gender, HIV infection, lung disease, dyspnoea and fatigue were associated with severe COVID-19.
14	2021	Frempong NK, et al.	This study reported Ghana's R0 as 3.21.
15	2021	Geldenhuys M, et al.	This study found for Africa that more surveillance has been initiated among bat populations (26,000 bats tested) than other wildlife and domestic animals. Though coronaviruses have been identified from approximately 7% of the total bats tested, surveillance among other animals identified coronaviruses in less than 1%.
16	2021	Gudina EK, et al.	This study from Ethiopia reported that COVID-19 control was challenged by lack of robust local scientific evidence, and the pandemic control measures were not adapted to local context and the outbreak patterns.
17	2021	Guleid FH, et al.	These authors reported that Africa's contribution to global health research including COVID-19 is low (1.3%) considering the high burden of infectious disease on the continent.
18	2022	Hosch S, et al.	This study reported a person from Equatorial Guinea to be co-infected with Beta and Delta VOCs.
19	2021	Inzaule SC, et al.	In Africa, COVID-19 caused reduced access to healthcare services including testing, treatment, and care support services, to structural impacts on drug stockouts, resource shortages, and malnutrition.
20	2022	Iyaniwura SA, et al.	This study reported estimates of COVID-19 across Africa to vary between 1.98 (Sudan) and 9.66 (Mauritius), with a median of 3.67.
21	2021	Jaspard M, et al.	This study showed that in referal health centers in west Africa (Burkina Faso and Guinea), the risk of death was higher in men, people aged 60 years and those with chronic hypertension.
22	2022	Koeppel KN, et al.	In South Africa, one health genomic surveillance identified transmission of a Delta variant from a zookeeper to three lions.
23	2022	Kêdoté NM, et al.	In Benin, the following risk factors related to COVID-19 were identified including lack of hand washing, permanent usage of air condition at workplaces, lack of knowledge about protective measures and no knowledge on the coronavirus incubation period.
24	2021	Kohnert D	They found that COVID 19 is threatening to push up to 58 million people into extreme poverty.
25	2021	Kumakamba, et al.	In bat samples from the Democratic Republic of Congo and Republic of Congo, RNA most closely related to sequences of the human common cold coronaviruses 229E or NL63 (> 80% nucleotide identities) was detected.
26	2021	Lamptey, et al.	This study showed that the duo variants ORF1ab/RdRp 4715L and S protein 614G variants, which are strongly linked to fatality rate were not significantly and positively correlated with fatality rates.
27	2022	Lekana-Douki S, et al.	Phylogenetic analysis of human samples from Gabon revealed that five sequences of the spike S gene showedthat two sequences had the D614G mutation.

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28	2021	Altable and Mois´ es de la Serna	This study found that multiple genetic and immunologic factors may be involved in the severity of COVID-19 in African individuals compared with the rest of the global population. One of these factors include direct actions of *Plasmodium falciparum* in the pathogenesis, expression of caspase-12, higher levels of LAIR-1-containing antibodies, and differential glycophorins expression.
29	2021	Madhi, et al.	This study reported that COVID-19 seropositivity in South Africa was 6.22-fold more likely in vaccinated (93.1%) vs unvaccinated (68.4%) individuals.
30	2020	Maganga, et al.	This study conducted in Gabon led to the identification of alphacoronaviruses in *H. gigas* and *H. cf. ruber* and betacoronaviruses in *H. gigas*. All Alphacoronavirus sequences clustered with Human coronavirus 229E (HCoV-229E).
31	2021	Mashige, et al.	This study found that among central African respondents, more men than women lost their businesses and contracted COVID-19 infections. Multivariable analysis revealed that respondents from East, Southern and Central Africa reported significantly higher impact of COVID-19.
32	2021	Fonkou, et al.	This study found that scholarly ties of North African countries were above all with the Kingdom of Saudi Arabia. In terms of number of publications, South Africa and Egypt were among the most productive countries.
33	2021	Morton, et al.	This study showed that PCR-negative/IgG-positive participants exhibited a nasal and systemic cytokine signature analogous to PCR-positive COVID-19 participants, predominated by chemokines and neutrophils and distinct from PCR-negative/IgG-negative participants. PCR-negative/IgG-positive participants had increased propensity for *Staphylococcus aureus* and *Streptococcus pneumoniae* colonisation. PCR-negative/IgG-positive individuals with high COVID-19 clinical suspicion had inflammatory profiles analogous to PCR-confirmed disease.
34	2020	Nachega, et al.	In the Democratic Republic of Congo, high mortality among patients aged < 20 years and with severe/critical disease.
35	2022	Nachega, et al.	In six sub-Saharan African countries (Democratic Republic of the Congo, Ghana, Kenya, Nigeria, South Africa, Uganda) a cohort study of children and adolescents hospitalized with COVID-19, showed high rates of morbidity and mortality were observed among infants and patients with noncommunicable disease comorbidities.
36	2021	Njonnou, et al.	This study attempts to show the action of immunomodulatory factors such as intestinal parasites, malaria infections, and BCG vaccine, cross immunization on COVID-19.
37	2022	Ntumvi, et al.	In wildlife from Cameroon multiple different variants of HCoV-229E-like viruses were detected.
38	2020	Oboh, et al.	This study found that Africa has contributed few genomes of Severe Acute Respiratory Syndrome-Coronavirus 2 (SARS-CoV-2) to the global pool in growing open access repositories.
39	2021	Olumade and Uzairue	This study reported the following common symptoms of COVID-19 including fever, cough, headache, and breathing problems.
40	2022	Osei, et al.	This study found that low incidence of COVID-19 in malaria-endemic regions supports the hypothesis that COVID-19 poor prognosis is prevented by malaria.
41	2021	Ossei, et al.	This study showed that during COVID-19 pandemic, post-mortem tests reveaveled an unconfirmed case of COVID-19 in Ghana and the client was left unattended to and died, having spent 8 days on the ward.
42	2022	Pandit, et al.	They found that the novel coronaviruses are likely to infect a greater number of host species than viruses from other families.
43	2021	Pulliam, et al.	In South Africa population, they found that the Omicron variant is associated with substantial ability to evade immunity from prior infection.
44	2021	Salim, et al.	They reported three new variants that have rapidly become dominant and have aroused concerns: B.1.1.7 (also known as VOC-202012/01), 501Y.V2 (B.1.351), and P.1 (B.1.1.28.1).
45	2020	Sevidzem, et al.	This paper reported that in Africa, COVID-19 had a low to moderate mortality rate. Eco-epidemiological data on the disease is weak and lacking for Africa.
46	2021	Simulundu, et al.	This phylogenomic analysis study of SARS-CoV-2 strain showed that it belonged to lineage B.1.1., sharing the last common ancestor with SARS-CoV-2 strains recovered from South Africa.
47	2021	Ssentongo, et al.	This study found the effect of the human development index, containment policies, testing capacity, specific humidity, temperature, and landlocked status of countries during COVID-19 on the local within-country and external between-country transmission.
48	2021	Tegally, et al.	This study revealed that three lineages (B.1.1.54, B.1.1.56 and C.1) spread widely in South Africa during the first wave, comprising ~42% of all infections in the country at the time. The newly identified C lineage of SARS-CoV-2, C.1, which has 16 nucleotide mutations as compared with the original Wuhan sequence, including one amino acid change on the spike protein, D614G.
49	2021	Tessema and Nkengasong	This study stated that several factors explain heterogeneity of COVID-19 in Africa, including the level of containment measures, demographic aspects, climate and environmental factors, host genetics and immune factors.
50	2020	Sekyere, et al.	This study highlighted that the onset of COVID-19 in South Africa brought to the fore systemic weaknesses in the quality of service delivery such as water and sanitation services, housing, healthcare, and infrastructure in various communities across the country
51	2021	Andersen, et al.	They found that variants that increase transmissibility of the disease also increase the incidence of new mutations, leading to a vicious circle.
52	2021	Wamai, et al.	This study report that factors explaining low COVID-19 spread in Africa include early government community-wide actions, population distribution, social contacts, and ecology of human habitation.
53	2021	Wilkinson, et al.	They found that ongoing transmission in many countries and increasing mobility led to the emergence and spread within the continent of many variants of concern and interest, such as B.1.351, B.1.525, A.23.1, and C.1.1.
54	2022	Wolter, et al.	They found a significant reduction in the hospitalisation among individuals with S gene target failure (SGTF) versus non-SGTF infections diagnosed during the same time period. SGTF-infected individuals had a significantly reduced odds of severe disease compared with individuals infected earlier with the delta variant.

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people (≥ 60 years) are at risk of the disease severity [9,13], a cohort study in six sub-Saharan African countries indicated multisystem inflammatory syndrome in children with COVID-19 [14]. A study conducted on pregnant women in South Africa revealed cough and hypertension as common COVID-19 clinical signs and symptoms were common in HIV positive women and with comorbidities. The complications of this disease in pregnant women are preterm labour and macerated stillbirths [12]. From most reports, the typical clinical signs associated with COVID-19 were: loss of taste, abdominal pains, myalgia/arthralgia, dyspnoea, fatigue, fever, cough, headache, and breathing problems [11,12,15,16].

Although COVID-19 presents low morbidity and mortality in Africa [2], as reported in a study from DR Congo [11], several reports present gender as a risk factor as males are more vulnerable than their female counterparts [9,10,13]. However, the conundrum of low COVID-19 mortality burden in SSA was suggested to be due to the following: sociodemographic age structure, widespread control methods [2], early Government community-wide actions, population distribution, social contacts, the prevalence of pre-existing conditions, trained immunity, genetic constitution, and broader socio-cultural dynamics [17]. Furthermore, multiple genetic and immunologic factors may be involved in the severity of COVID-19 in the African population compared to the rest of the global population [18]. These immunomodulatory factors include direct action of malaria, intestinal parasites, BCG vaccine and cross immunisation [19,20]. Indeed, a low incidence of COVID-19 in malaria-endemic regions of Africa supports the hypothesis that COVID-19 poor prognosis is prevented by malaria. It is assumed that malaria could link the reported low incidence of COVID-19 in Africa [3,21].

The SARS-CoV-2 continues to spread in Africa, and recent reports indicate that the basic reproduction number in the continent has declined from R0 ≤ 4 to R0 ~ 1 [22]. Furthermore, for some countries in West Africa, Southern Africa, North Africa, East Africa, Central Africa, and African Islands, the R0 ranges from 1.98 to 9.66 [23].

SARS-CoV-2 variants

The severe acute respiratory syndrome coronavirus 2 « SARS-CoV-2 » caused an outbreak of viral pneumonia in December 2019 that became the global COVID-19 pandemic. Since then, SARS-CoV-2 has naturally evolved. Whenever the virus replicates, there is a chance for genetic mutation.

The WHO has identified seven VOIs[1], four VOCs[2] and no VHCs[3]. Three of the four VOCs-Alpha, Beta, and Delta-have been detected in 46 African countries. Alpha has been observed in 36 countries. Beta has been identified in 32 countries. Delta, the most recent VOC to emerge, has been confirmed in 14 African countries. Seven countries - Democratic Republic of the Congo (DRC), Ghana, Kenya, Malawi, Mauritania, South Africa and Uganda - have shown all three variants (https://www.who.int/publications/m/item/weekly-epidemiological-update-on covid-19---25-may-2021). The outbreak of COVID-19 in most African countries was initiated by importations predominantly from Europe, which reduced after the early introduction of international travel restrictions. As the pandemic progressed, ongoing transmission in many countries and increasing mobility led to the emergence and spread within the continent of many VOCs, such as B.1.351, B.1.525, A.23.1, and C.1.1. Little is known about the up-to-date prevalence of genomic and geographical variations of the SARS-CoV-2 virus on the African continent [24]. Similarly, the progression of the SARS-CoV-2 pandemic in Africa has been heterogeneous, and the full impact is not yet well understood [25].

In Gabon, the following VOCs have been identified such as - The British Variant (B.1.1.7), Variant B.1.525, South African Variant (B.1.351) and Indian Variant in samples from international travellers [26]. In Zambia, phylogenomic analysis of patient samples revealed the lineage B.1.1 [27]. In Guinea, three distinct SARS-CoV-2 variants have dominated the epidemiological landscape since March 2020. In this country, a case of co-infection of two SARS-CoV-2 VOC, Beta and Delta, in a clinically asymptomatic and fully COVID-19 vaccinated man was identified [28]. Three lineages (B.1.1.54, B.1.1.56 and C.1) have spread widely in South Africa during the first wave [31]. The SARS-COV-2 Omicron variant detected in South Africa in November 2021 was demontrated to be widespread in the country [32,33].

Socio-economic impact outcomes

The spread and number of COVID-19 cases have been reported to be heterogeneous. Even within the same continent as Africa, environmental, sociocultural, economic, population density, and political differences could bring about discrepancies in the disease transmission dynamics. Indeed, it has been reported that Eastern and Southern African countries were adversely affected by the COVID-19 pandemic during lockdown [4]. During the COVID-19 pandemic, the governments of the various countries developed strategies to curb its spread. These rules were enforced at all levels of the society, including: public places, schools, offices, markets, and hospitals. The application of physical distancing and installation of sanitary taps targeted public areas and health facilities. Also, other countries like Uganda included refugee camps in their control program [34]. However, in Ghana, the imposition of preventive measures such as closing markets to ensure social distancing and decongestion has led to increased food prices and economic hardship [35]. Interestingly, another report from Ghana showed that the imposition of public health interventions such as border restrictions, intra-city movement, quarantine and isolation during the first phase of the pandemic reduced COVID-19 incidence [36]. In the case of Benin, risk factors associated with COVID-19 cases were lack of handwashing, constant usage of air conditioners in workplaces, little knowledge of protective measures and lack of knowledge of the coronavirus incubation period [37].

The health sector in most African countries was affected by the COVID-19 pandemic. In Ghana, several patients suspected of flu-like symptoms are sometimes denied the care they deserve due to the stigma associated with COVID-19, often in cases where laboratory tests are absent [21]. The COVID-19 pandemic presents multifaceted challenges to many healthcare programs, such as reduced access to healthcare services, including testing, treatment, drug stockouts, and malnutrition [38]. A report from South Africa indicated that COVID-19 has caused a weakness in the quality of service delivery such as water and sanitation services, housing, healthcare and

[1]Variants of Interest (VOI) are those that are suspected to evade the protection conferred by vaccines or to cause more severe disease or are more contagious than the original strain [29].

[2]Variants of Concern (VOC) is when data confirm that they cause one or more of the outcomes listed above for VOIs

[3]Variants of High Consequence (VHC) are the last class and is a variant that has clear evidence that prevention measures or Medical Countermeasures (MCMs) have significantly reduced effectiveness relative to previously circulating variants" [30].

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infrastructure [39]. The challenges of COVID-19 in Ethiopia are the lack of robust local scientific data and the pandemic control measures were not adapted to the local context and the outbreak patterns [40]. In Africa, estimates have already shown that many excess deaths, especially in the SSA region, will result not from COVID-19 but from disruptions in malnutrition programs and interruptions in implementing immunisation programs [17,41].

In Sudan, the COVID-19 impacted the economic and social rights of its citizens in the context of a fragile democratic transition and suspended constitutionalism [42]. The author argues that the pandemic has seriously affected the livelihood of vulnerable populations and their right to live dignified life. It has also led to the revival of modes of emerging rule and contributed to the slowing down of envisaged reforms. Low health system capacity, clinical and socio-economic factors are predictors of the reported burden of COVID-19 in Africa [43].

Spillover hosts

Most emerging dangerous human viruses, such as the SARS-CoV-2, have originated from wild animal hosts. Ongoing projects such as « ALSO-COVID-19 », « PREDICT », « Global Virome » has as aim to develop predictive tools that will enable the inference of the zoonotic potential of the increasing number of newly identified wildlife viruses from their genetic sequence. Comprehensive systems for early detection of wildlife virus spillover remains a vital response tool against the threat posed by zoonotic viruses [44].

More surveillance has been conducted among bat populations than other wildlife and domestic animal host species [45]. One genomic health surveillance revealed SARS-CoV-2 reverse zoonosis in pumas and lions in South Africa [46]. Evidence from this study suggests that the Delta variant was transmitted from a zoo keeper to three lions and the sequences of this strain were similar to that detected in humans in South Africa. In the Congo Basin, bats, rodents, and primates were sampled, and it occurred that bats had a high probability of positive infections with coronaviruses (CoVs) than the others. The detected RNA sequences corresponded to Alpha and Beta CoVs, with most of them similar to known CoVs and others being unique and potentially representing novel viruses [47]. In Cameroon, the CoV RNAs detected in bats represented 17 different genetic clusters, coinciding with the alpha and beta CoVs and sequences resembling human CoV-229E (HCoV-229E) [48]. In Gabon, the alpha CoV sequences identified in bats clustered with the human CoV-229E [49,50]. According to these reports from Cameroon and Gabon, the bat infection rate with CoVs was seasonal. From models predicting virus-host networks, novel CoVs are likely to infect more host species than viruses from other families [51].

CONCLUSION

In conclusion, some of the lessons and recommendations made after two years of living with the COVID-19 pandemic from Pan African studies are as follows:

1) The peculiar experience of African countries in managing the pandemic could serve as lessons for the global population given their long experience living with and tackling infectious diseases such as coronaviruses.

2) Regarding the challenges faced by African countries during the pandemic, there is need to design resilient and locally accepted public health interventions for the disease based on local findings. African countries need to learn from each other's methods used to fight against the pandemic. There is a need to develop the diagnostic capacity by constructing infrastructures and recruiting well-trained personnel to respond to future pandemics. Profiling the genomic and geographical variations of SARS-CoV-2 may be important for future decision-making.

3) Applying the lockdown policy enabled most countries to manage the pandemic, but this measure needs to be adequately implemented or adapted to specific contexts because most African countries faced severe issues such as food insecurity, adolescent pregnancy, gender-based violence, and disruption in treating other diseases.

4) The lesson from spillover host studies is that although bats were identified as potential spillover hosts of SARS-CoV-2, reverse zoonosis from humans in close proximity to wildlife has already been demonstrated in Africa. Hence human-wildlife interfaces should be regularly monitored for the emergence of dangerous zoonotic diseases.

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