



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



## Africa's preparedness towards COVID-19 vaccines: Demand and acceptability challenges

John Elvis Hagan Jr.<sup>a,d,\*</sup>, Bright Opoku Ahinkorah<sup>b</sup>, Abdul-Aziz Seidu<sup>c</sup>,  
Edward Kwabena Ameyaw<sup>b</sup>, Thomas Schack<sup>d</sup>

<sup>a</sup> Department of Health, Physical Education, and Recreation, University of Cape Coast, Cape Coast, Ghana

<sup>b</sup> School of Public Health, Faculty of Health, University of Technology Sydney, Australia

<sup>c</sup> Department of Population and Health, University of Cape Coast, Cape Coast, Ghana

<sup>d</sup> Faculty of Psychology and Sport Sciences, Neurocognition and Action-Biomechanics-Research Group, Bielefeld University, Bielefeld, Germany

### ARTICLE INFO

**Keywords:**  
Acceptability  
Africa  
Challenges  
COVID-19  
Demand  
Preparedness  
Vaccines

### ABSTRACT

To date, the response to coronavirus disease (COVID-19) in many African countries has been quick, forward-looking and adjustable in spite of the continent's limited resources. These responses were triggered by the continuous increase in cases and deaths, which have necessitated speedy development of an effective vaccine. It is anticipated that African governments and public health officials will show more transparency, and provide evidence-based strategies to support COVID-19 vaccines and design equitable as well as effective vaccine delivery plans for the populace. To this end, this review analysed Africa's preparedness and response towards COVID-19 vaccines, potential demand, acceptability and distribution challenges related to the management of the virus. The review takes stock of context-specific vaccine preparedness; the demand for vaccine and associated challenges; as well as vaccine accessibility and its distribution. The review offers insightful approaches and strategies by which African countries can maximize benefits from the COVID-19 vaccines to overcome the virus. These include the pursuance of vaccines that may help confer immunity or protection against the virus in the light of contextual circumstances of specific African countries, including sociocultural and economic issues among other factors.

### Introduction

The burden of the coronavirus disease 2019 (COVID-19) has been devastating on human health, social networks, and economic livelihoods across many societies, including Africa (Nkengasong and Mankoula, 2020). These rippling effects are likely to heighten because of the pandemic's unrelenting march across different geographical boundaries, especially in low- and middle-income societies.

The response to COVID-19 in many African countries has been quick, forward-looking and adjustable in spite of its limited resource (Nkengasong and Mankoula, 2020). These responses are due to the continuous increase in cases and deaths, demanding a speedy development of an effective vaccine. With second wave of the virus hitting many countries in Africa and the adherence to masking, social distancing, and contact tracing posing a huge challenge towards the spread of this virus, it appears a rapid vaccine development and uptake may help return life to normalcy in many countries (Kissler et al., 2020).

Although various governments have employed diverse strategies to mitigate the burden of the virus through public health interventions (e.g., rapid diagnostic testing, contact tracing, widespread masking, and physical distancing), it has become obvious that the uptake of a vaccine could effectively help manage the spread of COVID-19 (Gostin et al., 2020).

While the development of vaccines offers hope to many countries, these potential vaccines must first be approved by regulatory authorities, clinically trialed and distributed to scale, and made affordable to all populations (Gostin et al., 2020). Additionally, some unsavory or distasteful commentaries, which have portrayed Africa as the location for COVID-19 vaccine testing, have already generated public or social anxiety and apprehension towards acceptance (Rosenthal et al., 2020). Therefore, African governments and public health officials are compelled to show more transparency, provide evidence-based strategies to support COVID-19 vaccines, and design equitable and effective vaccine delivery plans for the populace (Weintraub et al., 2021). This review

\* Corresponding author.

E-mail address: [elvis.hagan@ucc.edu.gh](mailto:elvis.hagan@ucc.edu.gh) (J.E. Hagan Jr.).

<https://doi.org/10.1016/j.crbeha.2021.100048>

Received 25 February 2021; Received in revised form 6 May 2021; Accepted 10 May 2021

2666-5182/© 2021 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

analyses Africa's preparedness and response towards COVID-19 vaccines, potential demand, acceptability, and distribution challenges related to the management of the virus on the continent.

### Context-specific vaccine preparedness

In partnership with local governments and international organizations (e.g., World Health Organization [WHO], the Coalition for Epidemic Preparedness Innovations [CEPI]), the Africa centre for Disease Control (CDC) has implemented initiatives to speed up the development of COVID-19 vaccines and make sure they are distributed equitably across countries in Africa. The initiative includes the provision of a system to coordinate procurement for vaccine distribution and deployment of thousands of community health workers and emergency responders across the continent. The initiative was also to ensure that access to proven efficacious COVID-19 vaccines are provided to poorer nations to protect health-care workers and at least 20% of the most vulnerable populations (Africa CDC 2020).

Similar to other continents, Africa would require accessible vaccines to save the lives and health of its vulnerable populations, and to maintain economic development. As of 31st December 2020, approximately 2763,421 million people had reportedly contracted COVID-19 in Africa, with 2292,062 and 65,602 reported recoveries as well as deaths respectively (Africa CDC 2020). Therefore, a COVID-19 vaccine could help alleviate the current dire situation. One joint continental strategy for the management of COVID-19 is the urgent need to limit second wave local transmissions, prevent deaths and reduce associated damages. Till date, CDC Africa has reiterated the need for the continent's participation in clinical trials to guarantee that enough data is produced on the security and effectiveness of potential vaccine candidates among the region's populations.

The current COVID-19 clinical trial activity in Africa is limited (see Fig. 1), although it is reported that the continent has considerable experience and competencies to conduct clinical trials for preventive vaccines across a range of diseases (Africa CDC Consortium for COVID-19 Vaccine Clinical Trials, CONCVACT 2020; Nkengasong et al., 2020). Through the Africa CDC initiative, some inventoried sites to test vaccines in humans across the continent have been established. For example, 5 COVID-19 vaccine clinical trials (e.g., Biological: Bacille Calmette-Guerin (BCG); SARS-CoV-2 rS/Matrix-M1 Adjuvant; Biological: ChAdOx1 nCoV-19 with placebo comparators) have been established in South Africa because of the country's considerable trial capacity. Other countries (e.g., Egypt, Ghana, Guinea Bissau, Kenya) with varying capacities have all initiated trial activities in an attempt to facilitate successful vaccine implementation (Fig. 1, see (Nkengasong et al., 2020) for details). Available information suggest that several partner organizations in Africa are seriously working to aid further trials on potential COVID-19 vaccines. As candidates for vaccines' development increase because of the current upsurge, it is essential for collaborating agencies responsible for managing clinical trials in Africa to partner with vaccine developers to unearth other prospective and appropriate trial locations. Considerable support is required for the removal of impediments toward the commencement and progress of trials, with the utmost responsibility of ensuring the safety of trials and their ethical acceptability (Africa CDC Consortium for COVID-19 Vaccine Clinical Trials, CONCVACT 2020). To guarantee that the developed COVID-19 vaccines lead to general vaccination (i.e., 60%–70%) of the population, four well-coordinated strategies by local governments and public health officials are required to promote COVID-19 acceptance and effective vaccine distribution (Weintraub et al., 2021; WHO 2020a).

According to Weintraub et al., (2021), these inter-connected strategies include generating demand for the vaccine, allocating the vaccine, distributing the vaccine, and verifying coverage (see (Weintraub et al., 2021) for details).

For Africa to have 60% of its population vaccinated (i.e., a projected baseline prerequisite for herd immunity), the continent would require

nearly 1.5 billion doses of vaccine for its approximately 1.2 billion population, with at least two doses for a vaccine candidate (WHO 2020a). According to Africa CDC Annual Report (Africa CDC 2020), the required cost of vaccines and structural systems (e.g., trial and vaccination sites) needed for vaccine delivery is projected around \$7 billion to \$10 billion. Available estimates from the Africa CDC further suggests that Africa still needs additional huge funding to procure COVID-19 vaccines (Nkengasong et al., 2020; WHO 2020a).

The establishment of African CDC CONCVACT continental initiative is to bring together diverse local and international organizations as well as political leaders to mobilize enough resources to help accelerate the procurement of effective vaccines and boost the progression of COVID-19 vaccine trials in African countries. The idea of this initiative is to build partnership and strengthen the capacity of relevant state institutions and networks throughout the continent. It is essentially to promote scientific and clinical findings into substantive regional impact through political and regulatory engagement for COVID-19 management. A well-coordinated multi-sectoral approach is required to prepare for the development, acquisition, access, and administration of a COVID-19 vaccine. Achieving success in Africa demands collaborative efforts between political leaders, international partners (e.g., WHO), donors (e.g., World Bank, International Monetary Fund), regulatory agencies, private sector and the general populace.

Looking at the already enormous socioeconomic burden the current pandemic has brought on many countries, including Africa, developing and engineering mass production of vaccines require huge financial investments, and resources (Koirala et al., 2020). The huge financial outlay towards vaccine procurement could delay distribution and further aggravate the current damage. The Ebola experience is a classical example, where over 11,000 people were killed between 2013/2014, although a vaccine was in the developmental process, and later revealed to be effective in the prevention of Ebola, and that timely usage could have controlled the outbreak (Henao-Restrepo et al., 2017; Jones et al., 2005). Similarly, the SARS 2003 epidemic ended before vaccine development was finalized (Koirala et al., 2020). To avoid similar occurrence, a new financing strategy has been initiated in Africa to pay the billions of dollars for COVID-19 vaccinations, including advance payments to secure supply (Africa CDC 2020). Currently, the Africa Export Import Bank (Afreximbank) has agreed to a vaccine-financing outline for Africa which will allow mutual procurements of medical supplies and aid vaccine manufacture. African countries are to issue guarantees or collaterals to Afreximbank, after certification by CDC to facilitate approximately \$4 billion financial credit for vaccine orders from African suppliers.

All the ongoing preparations would be an exercise in futility if diverse populations on the continent are not keen to accept the vaccine, including follow-up dosages. It is essential to build public trust by minimizing public-health misinformation, disinformation and anti-vaccine sentiments across the populace (Ahinkorah et al., 2020). This goal can be achieved by providing local communities access, information, counselling and support related to the COVID-19 vaccine.

### The demand for vaccine and challenges

Vaccine development may take considerable time because as part of the standard requirements, vaccines must not only be protective but also safe. Compared to other medications that are administered to sick patients, vaccines are given to healthy people and require maximum safety precautions (Singh and Mehta, 2016). Therefore, generating demand for newly developed vaccines requires a better understanding of people's perceptions of vaccine safety, effectiveness and implementation of educational campaigns designed to meet context-specific needs of a population (Weintraub et al., 2021).

The WHO Increasing Vaccination Model emphasizes that people's thoughts and feelings (e.g., confidence, perceived risk, trust, safety concerns, and worry) about vaccines can influence their' desire to be vaccinated (WHO 2020b). Vaccine hesitancy has been acknowl-

# TESTING COVID-19 VACCINES IN AFRICA

Clinical trials are under way in many places on the continent; other sites have capacity or are developing it. These trials can help to ensure that vaccines are effective in African populations.

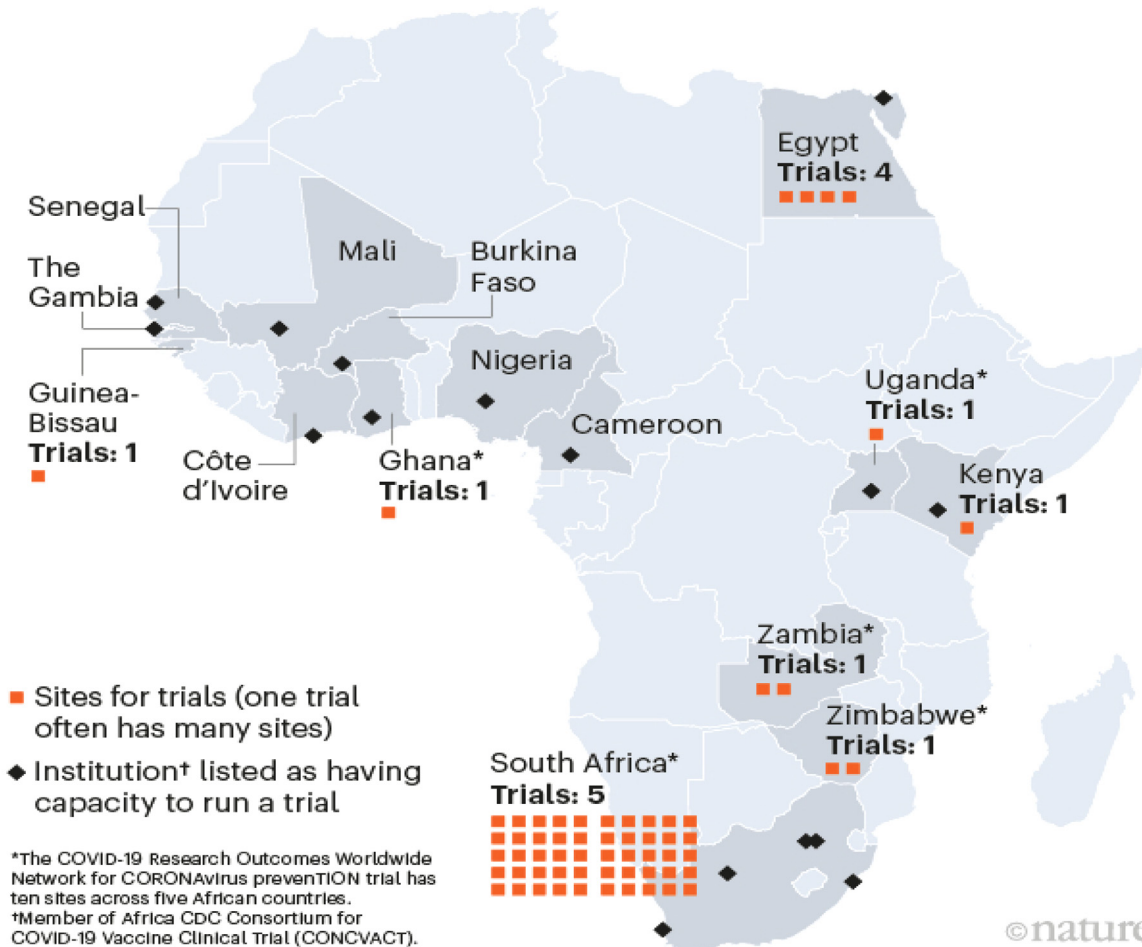


Fig. 1. Africa's vaccine clinical trials distribution sites (Africa CDC Consortium for COVID-19 Vaccine Clinical Trials, CONCVACT 2020).

edged as one of the top 10 threats to global health (WHO 2020b; Jarrett et al., 2015). With considerable socio-cultural complexities in Africa (Umvilighozo et al., 2020), generating demand for COVID-19 vaccines on the continent could be met with hesitancy and other misconceptions that need to be addressed. Therefore, readily available appropriate information, including anti-vaccine attitudes or beliefs, and the development of trust through educational campaigns are required (Fisher et al., 2020).

To date, empirical studies on public attitudes toward potential COVID-19 vaccines in Africa remain relatively sparse. However, research from elsewhere suggest that individuals' decision-making towards vaccination are complex and multi-faceted (Niankara et al., 2020; Salmon et al., 2015). It has been proven that individuals' attitudes toward vaccines range on a continuum, that is, from an end of complete vaccine rejection, to the other end of complete vaccine acceptance (Lane et al., 2018; Piltch-Loeb and DiClemente, 2020). Based on these two ends along the continuum, there are differing magnitudes of vaccine hesitancy (Carrieri et al., 2019; Larson et al., 2014). Therefore,

understanding well-packaged information on vaccines' developmental sequence ahead of schedule: pre-clinical testing, phased clinical trials, planned production, distribution and the uptake chain would be considered as crucial towards successful implementation at the national level against the COVID-19 pandemic in Africa (Koirala et al., 2020; Niankara et al., 2020). Empirical studies on COVID-19 vaccine acceptance and hesitancy in Africa are also required.

There are specific strategies to encourage COVID-19 demand grounded on perceptions, attitudes, and public trust. Using celebrities and respected public influencers has proven to be impactful in reshaping public attitudes, trust, and uptake of health interventions, including vaccines (Weintraub et al., 2021; Goldstein et al., 2015). Research in social sciences has already shown that influencers (e.g. cultural, sports, public health leaders) could help shape individuals' knowledge, attitudes, behaviors, and outcomes. According to some scholars, these personalities could have influential role during the COVID-19 pandemic, with social media platforms acting as a central avenue for health information (Weintraub et al., 2021; Kearney et al., 2019).

Africa, through its politicians, journalists, celebrities and religious leaders could leverage on this powerful avenue and become COVID-19 vaccines' brand ambassadors for promoting COVID-19 vaccines through storytelling, information sharing, and other forms of public engagement using social media, radio, television and other media platforms. Further, engaging grassroots level and local community partnership plays a crucial role in demand generation and promoting vaccine acceptance.

Granted that the demand for COVID-19 vaccines can be generated in Africa, questions surrounding who should first be recipients could be potential barriers. Quite often, limited resources are distributed to most privileged and some targeted influential people in societies instead of vulnerable groups (e.g., the aged, poor, physically challenged, women, children) during crisis management such as the current pandemic. Hence, decisions on COVID-19 vaccines should be prioritized on how to allocate the limited initial supply (see [Bubar et al., 2021](#) for details).

### Vaccines accessibility and distribution

Experiences of the 2014–2016 Ebola outbreak highlighted the need for a developed vaccine against the epidemic. However, there were some critical issues related to availability of a number of candidate vaccines, implementation of clinical trials, clinical assessments and regulatory limitations. Specifically, there were unique challenges with weak infrastructure such as limited laboratory facilities, including vaccination centers and logistics, and monitoring which lead to overcrowding and scarcity of spaces. Other major setbacks were limited experience with clinical trials, especially on trial design and the regulatory environment, operational issues, lack of funding for procurement and community engagement in Guinea, Liberia and Sierra Leone ([Henao-Restrepo et al., 2017](#); [Kennedy et al., 2016](#); [Mooney et al., 2018](#); [Walldorf et al., 2019](#)).

Based on the challenges faced during the Ebola outbreak, the under listed 4 specific multi-sectoral public health actions were jointly taken to help eradicate the epidemic through effective vaccine implementation:

1. Development of effective global collaboration on Ebola vaccines research and development pathways: The WHO, Africa regional partners (CDC), pharmaceutical companies, regulatory agencies, and nongovernmental organizations took joint actions toward the acceleration of Ebola vaccines' development through preclinical research to clinical trials.
2. Facilitation of scientific discussions on trial designs and parallel implementation of clinical trials for Ebola vaccine across different phases (i.e., 1, 2 and 3): The rationale was to take appropriate inventory of concerted efforts to assess candidate Ebola vaccines for safety and efficacy without undue delays.
3. Repeated assessment of vaccine characteristics to guide future usage of developed Ebola vaccines to manage and/ or avert potential outbreak: The idea was to provide effective guidance to vaccine developers to promote the use of Ebola vaccines for emergency use, to limit prevailing outbreak and stop multiple transmissions, and offer maximum protection of frontline healthcare workers and other high risk analogous groups.
4. Policy guidance on vaccine deployment challenges through technical support to affected countries: The overarching aim was to promote educational campaigns across affected countries to avoid hesitancy once vaccines were made available through well planned vaccination strategies ([Henao-Restrepo et al., 2017](#)).

Besides, for many parts of sub-Sahara Africa, issues related to science are often misunderstood because of socio-cultural beliefs and practices (e.g., religious beliefs, use of traditional medicine). Others include misinformation about the consequences of the vaccines safety and the perceived potential harm its implementation might have on the populace. For example, some misleading myths and numerous faith-related rumors led to the spread of wrong information on the cure of COVID-19 causing fears and mistrust of health care systems across affected countries

([WHO 2020b](#); [Kennedy et al., 2016](#)). Similar experiences were reported during the Ebola outbreak during which it was reported in Liberia that consenting volunteers on clinical trials feared contracting the Ebola virus through vaccine uptake ([Kennedy et al., 2016](#)). Lessons from these vaccine implementation challenges suggest that all earmarked COVID-19 candidate vaccines in Africa ought to be verified through effective and carefully monitored clinical trials until they are proven safe and/or effective. It is quite important that priority is also given to considerable community engagement involving appropriate partnerships between local communities, national governments, and other international partners to mitigate these inherent challenges associated with vaccine implementation programmes ([Henao-Restrepo et al., 2017](#)).

Considering the rampaging effects of COVID-19, it is important that vaccines are speedily validated through rigorous scientific processes before delivery and further distribution in Africa. Provisions for equitable access and affordable pricing require attention from stakeholders, especially for vulnerable persons ([Rosenthal et al., 2020](#)). To ultimately curtail the current spread of the virus on the continent, the imminent vaccine procurement and subsequent distribution ought to be responsive and efficient. Hence, the vaccines and accompanying logistics as well as data must be placed in the hands of appropriate personnel who could make the vaccine distribution efficient. For example, the supply chain challenges may include but not limited to getting the right vaccine product at the right temperature to the right person at the right time. Local experts should have at the back of their minds the inadequate vaccine related logistics (e.g., vials, stoppers) and other essential products to package and make available for transportation ([Weintraub et al., 2021](#)). It is important that the supply chain and distribution strategies in Africa countries are well-planned, with effective tracking, and monitoring network and alternate strategies for imminent vaccine delivery. There is also the need for innovative technology (e.g., use of drone flights, digital services) to track medical deliveries, including vaccines. From a long-term perspective, Africa leadership, partnering organizations and donor agencies should facilitate the improvement of the manufacturing capacity of individual countries on vaccine development through rigorous scientific, ethical and legal frameworks.

### Conclusions

The novel coronavirus (COVID-19) has presented unique and enormous public health challenges for Africa and other societies. Given the high burden of this infectious disease, strategies to combat it not only require the implementation of non-pharmaceutical interventions but also the pursuance of vaccines that may help confer immunity or protection against the virus. Although the development of vaccines is currently ongoing, prior history on vaccine programmes suggests that there could be numerous challenges related to context-specific preparedness on finances, demand, acceptability, delivery and possible distribution. Up until now, approximately 40 African countries have established national vaccination strategies before the arrival of COVID-19 vaccines with technical support and guidance of WHO ([WHO 2021](#)). For instance, Ghana is the first sub-Saharan nation to receive vaccines through the [COVAX facility](#) after demonstrating sufficient logistical preparations and appropriate coordination through government total commitment and multi-sectoral partnership, including the use of mobile vaccination teams to reach people in remote areas of the country and vulnerable groups (e.g., elderly) ([WHO 2021](#)).

Considering Africa's unique healthcare, sociocultural and economic situation, the implementation of the public health interventions for vaccine preparedness and response to the COVID-19 pandemic should be prioritised. Therefore, it is imperative that African countries develop continued funding opportunities and enhance the capacity of existing health systems to facilitate rapid development of vaccine and distribution-chain management. National, public health institutions (e.g., Africa CDC), international organisations and donor agencies need

to cooperate and collaborate to guarantee vaccine implementation success on the continent.

#### Data and Code availability statement

There is no data or code used in the article.

#### Declaration of Competing Interest

None.

#### Acknowledgements

The authors sincerely thank Neurocognition and Action-Biomechanics Research Group, Bielefeld University, Germany for providing financial support for the article processing charge.

#### Funding

None

#### Ethical approval

Not required because the manuscript is a mini-review.

#### Authors' Contribution

JEH and BOA conceived the idea. JEH, BOA, AS, EKA and TS prepared the initial draft of the manuscript. All authors thoroughly revised and approved the final version of the paper.

#### References

- Africa CDC (2020). Annual Progress Report 2020. Available online at: <https://africacdc.org/covid-19/> (accessed February 4, 2021).
- Africa CDC Consortium for COVID-19 Vaccine Clinical Trials, CONCVACT, 2020. Addendum to the Africa COVID-19 vaccine development and access strategy. Available online at: <https://africacdc.org/covid-19/> (accessed February 4, 2021).
- Ahinkorah, B.O., Ameyaw, E.K., Hagan Jr, J.E., Seidu, A.A., Schack, T., 2020. Rising above misinformation or fake news in Africa: another strategy to control COVID-19 spread. *Front. Commun.* 5, 45. doi:10.3389/fcomm.2020.00045.
- Bubar, K.M., Reinholt, K., Kissler, S.M., Lipsitch, M., Cobey, S., Grad, Y.H., Larremore, D.B., 2021. Model-informed COVID-19 vaccine prioritization strategies by age and serostatus. *Science*. Available from <https://www.medrxiv.org/content/10.1101/2020.09.08.20190629v1.full.pdf>.
- Carrieri, V., Madio, L., Principe, F., 2019. Vaccine hesitancy and (fake) news: quasi-experimental evidence from Italy. *Health Econ.* 28 (11), 1377–1382.
- WHO. Emerging lessons from Africa's COVID-19 vaccine rollout, 2021. <https://www.afro.who.int/news/emerging-lessons-africas-covid-19-vaccine-rollout> (accessed on 28 April 2021).
- Fisher, K.A., Bloomstone, S.J., Walder, J., Crawford, S., Fouayzi, H., Mazor, K.M., 2020. Attitudes toward a potential SARS-CoV-2 vaccine: a survey of US adults. *Ann. Intern. Med.* 173 (12), 964–973.
- Goldstein, S., MacDonald, N.E., Guirguis, S., 2015. Health communication and vaccine hesitancy. *Vaccine* 33 (34), 4212–4214.
- Gostin, L.O., Karim, S.A., Mason Meier, B., 2020. Facilitating access to a COVID-19 vaccine through global health law. *J. Law Med. Ethics* 48 (3), 622–626.
- Henao-Restrepo, A.M., Camacho, A., Longini, I.M., Watson, C.H., Edmunds, W.J., Eger, M., ..., Kiely, M.P., 2017. Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomised trial (Ebola Ça Suffit!). *Lancet North Am. Ed.* 389 (10068), 505–518.
- Jarrett, C., Wilson, R., O'Leary, M., Eckersberger, E., Larson, H.J., 2015. Strategies for addressing vaccine hesitancy—a systematic review. *Vaccine* 33 (34), 4180–4190.
- Jones, S.M., Feldmann, H., Ströher, U., Geisbert, J.B., Fernando, L., Grolla, A., ..., Geisbert, T.W., 2005. Live attenuated recombinant vaccine protects nonhuman primates against Ebola and Marburg viruses. *Nat. Med.* 11 (7), 786–790.
- Kearney, M.D., Selvan, P., Hauer, M.K., Leader, A.E., Massey, P.M., 2019. Characterizing HPV vaccine sentiments and content on Instagram. *Health Educ. Behav.* 46 (2\_suppl), 37S–48S.
- Kennedy, S.B., Neaton, J.D., Lane, H.C., Kieh, M.W., Massaquoi, M.B., Touchette, N.A., Nason, M.C., Follmann, D.A., Boley, F.K., Johnson, M.P., Larson, G., 2016. Implementation of an Ebola virus disease vaccine clinical trial during the Ebola epidemic in Liberia: design, procedures, and challenges. *Clin. Trials* 13 (1), 49–56. doi:10.1177/1740774515621037, Feb.
- Kissler, S.M., Tedijanto, C., Goldstein, E., Grad, Y.H., Lipsitch, M., 2020. Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. *Science* 368 (6493), 860–868.
- Koirala, A., Joo, Y.J., Khatami, A., Chiu, C., Britton, P.N., 2020. Vaccines for COVID-19: the current state of play. *Paediatr Respir. Rev.* 35, 43–49.
- Lane, S., MacDonald, N.E., Marti, M., Dumolard, L., 2018. Vaccine hesitancy around the globe: analysis of three years of WHO/UNICEF Joint Reporting Form data-2015–2017. *Vaccine* 36 (26), 3861–3867.
- Larson, H.J., Jarrett, C., Eckersberger, E., Smith, D.M., Paterson, P., 2014. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: a systematic review of published literature, 2007–2012. *Vaccine* 32 (19), 2150–2159.
- Mooney, T., Smout, E., Leigh, B., Greenwood, B., Enria, L., Ishola, D., Manno, D., Samai, M., Douoguih, M., Watson-Jones, D., 2018. EBOVAC-Salome: lessons learned from implementing an Ebola vaccine trial in an Ebola-affected country. *Clin. Trials* 15 (5), 436–443. doi:10.1177/1740774518780678, Oct.
- Niankara, I., Muqattash, R., Niankara, A., Traoret, R.I., 2020. COVID-19 vaccine development in a quadruple helix innovation system: uncovering the preferences of the Fourth Helix in the UAE. *J. Open Innov.* 6 (4), 132.
- Nkengasong, J.N., Mankoula, W., 2020. Looming threat of COVID-19 infection in Africa: act collectively, and fast. *Lancet North Am. Ed.* 395 (10227), 841–842.
- Nkengasong, J.N., Ndembi, N., Tshangela, A., Raji, T., 2020. COVID-19 vaccines: how to ensure Africa has access. *Nature* 586, 197–199. doi:10.1038/d41586-020-02774-8.
- Piltch-Loeb, R., DiClemente, R., 2020. The vaccine uptake continuum: applying social science theory to shift vaccine hesitancy. *Vaccines* 8 (1), 76.
- Rosenthal, P.J., Breman, J.G., Djimde, A.A., John, C.C., Kanya, M.R., Leke, R.G., ..., Bausch, D.G., 2020. COVID-19: shining the light on Africa. *Am. J. Trop. Med. Hyg.* 102 (6), 1145.
- Salmon, D.A., Dudley, M.Z., Glanz, J.M., Omer, S.B., 2015. Vaccine hesitancy: causes, consequences, and a call to action. *Vaccine* 33, D66–D71.
- Singh, K., Mehta, S., 2016. The clinical development process for a novel preventive vaccine: an overview. *J. Postgrad. Med.* 62 (1), 4.
- Umvilighozo, G., Mupfumi, L., Sonela, N., Naicker, D., Obuku, E.A., Koofhethile, C., ..., Balinda, S.N., 2020. Sub-Saharan Africa preparedness and response to the COVID-19 pandemic: a perspective of early career African scientists. *Wellcome Open Res.* 5.
- Walldorf, J.A., Cloessner, E.A., Hyde, T.B., MacNeil, A., Bennett, S.D., Carter, R.J., Redd, J.T., Marston, B.J., 2019. Considerations for use of Ebola vaccine during an emergency response. *Vaccine* 37 (48), 7190–7200. doi:10.1016/j.vaccine.2017.08.058, Nov 15.
- Weintraub, R.L., Subramanian, L., Karlage, A., Ahmad, I., Rosenberg, J., 2021. COVID-19 Vaccine to vaccination: why leaders must invest in delivery strategies now: analysis describe lessons learned from past pandemics and vaccine campaigns about the path to successful vaccine delivery for COVID-19. *Health Aff.* 10–1377.
- WHO (2020a). DRAFT Landscape of COVID-19 candidate vaccines <https://www.who.int/who-documents-detail/draft-landscape-of-covid-19-candidate-vaccines>.
- WHO (2020b). Improving vaccination demand and addressing hesitancy [Internet]. Geneva. Available from: [https://www.who.int/immunization/programmes\\_systems/vaccine\\_hesitancy/en/](https://www.who.int/immunization/programmes_systems/vaccine_hesitancy/en/).