



Research Article

Shielding Africa, Protecting the World: Unleashing the Power of Preventative Use of Ebola Vaccines

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Abstract

Africa CDC recently conducted a comprehensive risk ranking assessment of epidemic-prone diseases across the continent, identifying Ebola as one of the top 19 infectious diseases with the highest scores in disease severity risk and epidemic potential. The Ebolaviruses first described in the Democratic Republic of the Congo (DRC) in 1976 have left a harrowing trail across sub-Saharan Africa, triggering no less than 34 Ebola outbreaks in 11 sub-Saharan Africa countries, a statistic further compounded by the recent outbreak in Uganda in 2022. At present, the World Health Organization (WHO) has approved two Ebola vaccines, including Ervebo and two-component Zabdeno and Mvabea boost vaccines, for use by individuals above the age of 1 year, including pregnant women as per the Strategic Advisory Group of Experts on Immunization (SAGE) recommendations. The use of these vaccines has demonstrated noteworthy efficacy in safeguarding against Ebola in most African communities and frontline health workers in Ebola-endemic countries such as Sierra Leone, Guinea, and Liberia, among others. Unfortunately, the uptake of these vaccines in Ebola-endemic countries remains dishearteningly constrained despite their availability due to, among other things, the unpredictable timing of outbreaks, sub-optimal surveillance, vaccine demand volatility, palpable vaccine hesitancy, and fragile health infrastructure. Addressing these challenges requires a multifaceted approach that includes a synergy of partnerships between governments, communities, development partners, and private sector partners, such as pharmaceuticals. Recognizing that outbreaks originate and seize at the community level, the imperative of confronting hesitancy through sustained proactive community engagement and utilizing promising vaccination strategies such as ring vaccination must be encouraged. Governments must increase investments to strengthen the regulatory environment for timely access to vaccine stockpiles, robust and cost-effective Ebola vaccination programs for at-risk populations, and preventative use for the health workforce. The International Coordinating Group (ICG) on Vaccine Provision also recommends that national and international health authorities initiate vaccine access by submitting a request to the ICG. This opportunity is at no cost for GAVI-eligible countries and on a reimbursement basis for non-eligible countries. In parallel, Africa CDC is also working closely with Member States on the continent to increase availability and access to medical countermeasures, which include therapeutics, vaccines, and diagnostics, making it critical that Africa CDC is included in the ICG. This will promote timely issue profiling and resolution for increased demand for vaccine stockpiles across the continent where they are needed most as the continent moves towards enhanced health security.

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Keywords

Ebola, Vaccines, Sub-Saharan Africa, ICG, SAGE, Africa CDC, Health Security

1. Introduction

This paper offers a comprehensive update on Ebola endemicity on the African continent, shedding light on the remarkable progress made in the production of vaccines and the potential benefits of the widespread use of vaccines in proactively preventing Ebola outbreaks in Africa. The paper also highlights the critical success factors necessary to improve the uptake of vaccines on the continent. Guidance has also been provided on how countries can access the vaccine stockpile to enhance the preventative use of the Ebola vaccine. Knowledge and insights from this paper have the potential to lay the groundwork for policy development, catalyze collaboration and partnerships essential for the broader adoption and use of Ebola prevention vaccination strategies to shield Africa against the devastating impacts of Ebola, mitigate the impact of outbreaks, and pave the way for economic and social development in Africa [1].

2. Ebola Remains a High-Priority Infectious Disease on the African Continent

The Ebolaviruses first described in the Democratic Republic of the Congo (DRC) in 1976 have left a harrowing trail across sub-Saharan Africa. They have triggered no less than 34 Ebola outbreaks in 11 sub-Saharan Africa countries, culminating in a total of 34 356 cases and 14 823 deaths as of 2019, a statistic further compounded by the recent outbreak in Uganda in 2022. The recurrent emergence of sporadic Ebola Viral Disease (EVD) outbreaks continues to pose a dark shadow on public health in Africa, causing loss of life, economic disruption, straining the healthcare system and families, and warranting strategies for preventing future epidemics [3, 4]. Exposures to the Ebola virus are manifold and can be traced to the heightened struggle for livelihoods resulting in increased human-wildlife/forest interaction and exposure, encroachments into forests for infrastructure developments, burgeoning urban populations, including the historical inadequacy of preparedness and response measures stemming from poor public health infrastructure, and the delayed and sometimes fragmented response by both governments and development partners. [2, 5, 6]. Africa Center for Disease Control (CDC) has also recently concluded a prioritization/risk ranking of epidemic-prone diseases on the continent to inform planning and resource allocation to manage prevention/mitigation and response actions to health emergencies.

Ebola, Cholera, and COVID-19 were observed to be among the top 19 infectious diseases with the highest scores for disease severity risk and epidemic potential.

3. Promising Strategies for Ebola Prevention and Control

It is, therefore, evident that imperative and well-orchestrated actions are needed for better coordination in developing and deploying Ebola vaccines as a pivotal tool in averting future outbreaks. Previous Ebola outbreaks, for instance, in West Africa, Sudan, DRC, and Sierra Leone, have glaringly illuminated the pressing need for accelerated vaccine development and utilization in combating the Ebola virus [7–9]. At present, the World Health Organization (WHO) has approved two Ebola vaccines, including Ervebo and two-component Zabdeno and Mvabea boost vaccines, for use by individuals above the age of 1 year, including pregnant women as per the recommendations of the Strategic Advisory Group of Experts on Immunization (SAGE). SAGE working group plays a technical advisory role to the WHO in many areas, including Ebola. Their recommendation delineates the utilization of the Ervebo vaccine for Ebola outbreak response caused by the Zaire strain, while the multivalent Zabdeno and Mvabea boost vaccine is recommended for other Ebola strains or preventive vaccination opportunities [10–12]. The use of these vaccines has demonstrated noteworthy efficacy in safeguarding against Ebola in most African communities and frontline health workers in Ebola-endemic countries such as Sierra Leone, Guinea, and Liberia, among others [13, 14].

Integrating Ebola vaccination into the existing healthcare system through comprehensive vaccination campaigns that target high-risk populations in Ebola-prone regions is critical in bolstering the prevention of outbreaks, response capabilities, and long-term vaccine stockpile management. In the 2018–2020 Ebola outbreak in the DRC, a remarkable feat was achieved, vaccinating over 300,000 people, including health care and frontline workers, against Ebola following the astute application of the "ring vaccination" strategy [15]. The strategy was proven to be 97.5% effective in reducing death among those infected with Ebola. The strategy ensures that people at risk, including contacts and contacts of contacts, healthcare, and frontline workers in the affected and neighboring areas of the outbreak, are vaccinated, promoting the

prudent use of Ebola vaccines [16]. In addition to ring vaccination, other vaccination strategies have included temporary 'pop-up' sites, which have been a beacon of hope in ensuring discrete, anonymous vaccination for those who may face stigmatization in conflict areas [17–20]. Targeted geographic vaccination has also been employed in places like the DRC, where entire communities in a specific geographic area or village at high risk of Ebola outbreaks are vaccinated, bypassing the need to identify contacts. [12]. The approach successfully halted the spread of the outbreaks in DRC, extending the Ebola vaccine coverage to a staggering 90 percent of the population [20].

That said, the uptake of Ebola vaccines in Ebola-endemic countries remains dishearteningly constrained despite their availability. This is in part attributed to the unpredictable timing of outbreaks, their size, and evolving epidemiology, sub-optimal surveillance, which complicates prediction and preparedness, demand volatility where Ebola endemic countries fail to prioritize vaccination programs for the preventative use of Ebola vaccines, and in-country operational constraints that hamper macro and micro planning during outbreaks. Additionally, palpable vaccine hesitancy has been reported amongst communities targeted in the vaccination programs. The hesitancy is more often pronounced in poor segments of society and finds its roots in an intricate web of fear, stigma, traditional cultural practices, and misconceptions about the vaccine in most affected communities [14, 21, 22]. Adding to the complexity, the region has reported fragile health infrastructure and a suboptimal demand for health services [23]. Further, limited government funding for the prevention and containment of Ebola in the continent casts a shadow over service delivery, inadvertently contributing to vaccine hesitancy partly due to inadequate supplies and the reuse of equipment likely to increase the risk faced by medical personnel [23]. The historical backdrop of government mistrust, limited intergovernmental cooperation, and the substantial influence of big pharmaceutical companies impact Ebola vaccine utilization and distribution [8, 17]. Unfortunately, the looming specter of Ebola resurgence underscores the urgency of addressing these obstacles and seizes the pivotal opportunity to chart a course towards incremental deployment of the vaccine among at-risk populations to safeguard Africa's health and well-being.

4. Call to Action for Governments to Promote the Preventative Use of Vaccines in Ebola-endemic Countries

Addressing these challenges requires a multifaceted approach. To guarantee timely vaccine access and utilization among at-risk populations, the stockpiling of Ebola vaccines is imperative, offering a shield against human suffering, response costs, and economic setbacks. The International Coordinating Group on Vaccine Provision (ICG) established in

1997, plays a pivotal role in managing and coordinating emergency vaccine supplies and antibiotics/antivirals to any country during outbreaks. In a significant development, ICG announced the establishment of a global Ebola vaccine stockpile in January of 2021, fortifying our readiness to combat and ensure outbreak response. National and international health authorities can initiate vaccine access by submitting a request to the ICG, with a decision made within 48-hours. As of 2023, the Global Alliance for Vaccines and Immunization (GAVI)-eligible countries can request and receive Ebola Vaccines from the stockpile at no cost and even receive some financial support for implementation, subject to the current ICG application mechanism and meeting key requirements. Therefore, governments seeking to implement preventive Ebola vaccinations must explore this avenue. Non-eligible countries can still access vaccines for emergencies and prevention but would be required to reimburse the stockpile. In parallel, Africa CDC is also working closely with Member States on the continent to increase availability and access to medical countermeasures, which include therapeutics, vaccines, and diagnostics. The efforts extend to accelerating research and innovations, enhancing healthcare worker protection, and strengthening surveillance and early warning systems. Africa CDC's instrumental role in the latest Ebola outbreak in Uganda underscores its commitment to enhance Ebola preparedness in the region. During the outbreak, Africa CDC supported coordination, Emergency Operations Center (EOC) operations, facilitating cross-border collaboration with neighboring countries, training of health workforce and village health teams on Infection Prevention and Control, Community and Events Based Surveillance and mortality surveillance, logistics, including post-recovery efforts such as bolstering laboratory and diagnostic capacity through training and supply of essential testing reagents and genomic sequencing, coupled with rigorous research endeavors.

Despite the abundant opportunities to access the vaccine stockpiles, there remains a stark underutilization of the stockpile for preventive vaccination at the country level. There's, therefore, a resounding call to governments to allocate adequate funding for infrastructural upgrades to facilitate critical delivery of healthcare services, with a particular focus on Ebola vaccination programs [25–28]. This will not only alleviate the strain on overwhelmed healthcare facilities but also ensure adequate staffing levels and preventive vaccination of frontline healthcare workers - a paramount step in averting disease outbreaks and diminishing the risks faced by the healthcare sector. Governments should also prioritize strengthening their respective National Regulatory Authorities to improve timely access to the vaccine stockpiles. Proactive surveillance and monitoring of events that could precipitate Ebola outbreaks in at-risk populations are paramount, serving as a frontline defense against the reemergence of Ebola [7]. Africa CDC is working closely with countries to establish robust early warning, alert, and response systems for detecting diseases and public health events on the continent.

This endeavor encompasses establishing guidelines and implementing an Event-based surveillance system and Event Management System, including capacity building for detecting and reporting suspected cases.

A fundamental element of scaling the preventative use of the Ebola vaccine includes confronting hesitancy to improve vaccine confidence. This involves the sustained proactive community engagement to dispel vaccine-related misinformation and misconceptions, bolster vaccine acceptance as well and strengthen existing community networks involving community leaders and local organizations. Amref Health Africa was among the key stakeholders involved in Risk Communication and Community Engagement efforts in the recent Ebola outbreak in Uganda. Initiating vaccine use in communities hinges on trust, fostering open communication, and profound respect for cultural and social values [24]. In an outbreak situation, policies mandating mandatory vaccination should be implemented to ensure widespread vaccine use. These policies should advocate for the use of Ebola vaccines. They should be operationalized through community-driven initiatives and training for key community members and gatekeepers to provide them with the accurate knowledge and skills needed to promote vaccine acceptance. These policies could lay out approaches for community surveillance, tracing undetected suspected cases and survivors' contacts [29].

Additionally, the policies could be aligned with bylaws to discourage stigmatization of victims and survivors, fostering a climate of compassion and support within communities. Further, the need for external support could be stipulated to support community ownership of vaccine use through community initiatives to support local actions and the need for support groups in the community. Together, these measures pave the way for comprehensive community engagement, acceptance, and the effective promotion of preventative Ebola vaccine use.

5. Conclusion

With Ebola ranking amongst the top infectious diseases on the African continent, it is evident that imperative and well-orchestrated actions are needed for the successful development and deployment of Ebola vaccines as a pivotal tool in averting future outbreaks. A profound synergy of public-private partnerships is indispensable in uniting governments, development partners, private sector partners such as pharmaceuticals, and communities to maximize acceptance and equitable access to Ebola vaccines. An essential step in this direction is the inclusion of Africa CDC into the ICG to promote timely issue profiling and resolution for increased demand for vaccine stockpiles across the continent where they are most needed. Governments must also increase investments to strengthen the regulatory environment to encourage timely access to vaccine stockpiles for preventative use in their respective countries. Investments must include strengthening local capacities for robust Ebola vac-

cination programs that promote cost-effective preventative utilization of the vaccines for at-risk populations through strategies such as ring vaccination and preventative use for the health workforce - a paramount step in averting disease outbreaks and diminishing the risks faced by the healthcare sector. Recognizing that outbreaks originate and seize at the community level, the imperative of confronting hesitancy to improve vaccine confidence is paramount. This will involve sustained proactive community engagement to dispel vaccine-related misinformation and misconceptions, bolster vaccine acceptance as well and strengthen existing community networks involving community leaders and local organizations. Policy development, collaboration, and partnerships essential for the broader adoption and use of Ebola prevention vaccination strategies to shield Africa against the devastating impacts of Ebola, mitigate the impact of outbreaks and pave the way for economic and social development in Africa will be necessary as the continent moves towards enhanced health security.

Abbreviations

Africa CDC: Africa Centers for Disease Control
BMI: Body Mass Index
COVID: Coronavirus Disease
DRC: Democratic Republic of Congo
EOC: Emergency Operations Center
EVD: Ebola Viral Disease
GAVI: Global Alliance for Vaccines and Immunization
ICG: International Coordinating Group
SAGE: Strategic Advisory Group of Experts
WHO: World Health Organization

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Salmon DA, Dudley MZ, Glanz JM, Omer SB. Vaccine Hesitancy: Causes, Consequences, and a Call to Action. *Am J Prev Med* [Internet]. 2015 Nov 1 [cited 2023 Sep 28]; 49(6): S391–8. Available from: <http://www.ajpmonline.org/article/S0749379715003141/fulltext>
- [2] Rugarabamu S, Mboera L, Rweyemamu M, Mwanyika G, Lutwama J, Paweska J, et al. Forty-two years of responding to Ebola virus outbreaks in Sub-Saharan Africa: a review. *BMJ Glob Health* [Internet]. 2020 Mar 1 [cited 2023 Sep 26]; 5(3): e001955. Available from: <https://gh.bmj.com/content/5/3/e001955>
- [3] Elston JW, Cartwright C, Ndumbi P, Wright J. The health impact of the 2014-15 Ebola outbreak. *Public Health*. 2017 Feb; 143: 60-70. <https://doi.org/10.1016/j.puhe.2016.10.020>. Epub 2016 Nov 29. PMID: 28159028. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9159599/>

- [4] Onyekuru NA, Ihemezie EJ, Ezea CP, Apeh CC, Onyekuru BO. Impacts of Ebola disease outbreak in West Africa: Implications for government and public health preparedness and lessons from COVID-19. *Sci Afr.* 2023 Mar; 19: e01513. <https://doi.org/10.1016/j.sciaf.2022.e01513>. Epub 2022 Dec 17. PMID: 36570591; PMCID: PMC9759305.
- [5] CDC. History of Ebola Disease Outbreaks | History | Ebola (Ebola Virus Disease) | CDC [Internet]. 2023 [cited 2023 Sep 26]. Available from: <https://www.cdc.gov/vhf/ebola/history/chronology.html>
- [6] Munster VJ, Bausch DG, de Wit E, Fischer R, Kobinger G, Muñoz-Fontela C, et al. Outbreaks in a Rapidly Changing Central Africa — Lessons from Ebola. *New England Journal of Medicine* [Internet]. 2018 Sep 27 [cited 2023 Sep 27]; 379(13): 1198–201. Available from: <https://www.nejm.org/doi/10.1056/NEJMp1807691>
- [7] Malik S, Kishore S, Nag S, Dhasmana A, Preetam S, Mitra O, León-Figueroa DA, Mohanty A, Chattu VK, Assefi M, Padhi BK, Sah R. Ebola Virus Disease Vaccines: Development, Current Perspectives & Challenges. *Vaccines (Basel)*. 2023 Jan 26; 11(2): 268. <https://doi.org/10.3390/vaccines11020268>. PMID: 36851146; PMCID: PMC9963029.
- [8] Sharma AR, Lee YH, Nath S, Lee SS. Recent developments and strategies of Ebola virus vaccines. *Curr Opin Pharmacol.* 2021 Oct; 60: 46–53. <https://doi.org/10.1016/j.coph.2021.06.008>. Epub 2021 Jul 27. PMID: 34329960.
- [9] Sridhar S. Clinical development of Ebola vaccines. *Ther Adv Vaccines.* 2015 Sep; 3(5–6): 125–38. <https://doi.org/10.1177/2051013615611017>. PMID: 26668751; PMCID: PMC4667768.
- [10] Henao-Restrepo AM, Camacho A, Longini IM, Watson CH, Edmunds WJ, Egger M, Carroll MW, Dean NE, Diatta I, Doumbia M, Draguez B, Duraffour S, Enwere G, Grais R, Gunther S, Gsell PS, Hossmann S, Watle SV, Kondé MK, Kéfa S, Kone S, Kuisma E, Levine MM, Mandal S, Mauget T, Norheim G, Riveros X, Soumah A, Trelle S, Vicari AS, Røttingen JA, Kieny MP. Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomized trial (Ebola Ça Suffit!). *Lancet.* 2017 Feb 4; 389(10068): 505–518. [https://doi.org/10.1016/S0140-6736\(16\)32621-6](https://doi.org/10.1016/S0140-6736(16)32621-6). Epub 2016 Dec 23. Erratum in: *Lancet.* 2017 Feb 4; 389(10068): 504. Erratum in: *Lancet.* 2017 Feb 4; 389(10068): 504. PMID: 28017403; PMCID: PMC5364328.
- [11] WHO. Ebola virus disease [Internet]. 2023 [cited 2023 Sep 26]. Available from: https://www.who.int/health-topics/ebola#tab=tab_3
- [12] WHO. Report of the Strategic Advisory Group of Experts (SAGE) on Immunization. 2018 Oct [cited 2023 Sep 28]; Available from: <https://iris.who.int/bitstream/handle/10665/276544/WER9349.pdf?ua=1>
- [13] Muhammed O Afolabi, Ph.D, David Ishola, Ph.D., Daniela Manno, MD, Babajide Keshinro, FWACP, Viki Bockstal, Ph.D., Baimba Rogers, MSc, et al. Safety and immunogenicity of the two-dose heterologous Ad26. ZEBOV and MVA-BN-Filo Ebola vaccine regimen in children in Sierra Leone: a randomized, double-blind, controlled trial. Published: September 13, 2021. DOI: [https://doi.org/10.1016/S1473-3099\(21\)00128-6](https://doi.org/10.1016/S1473-3099(21)00128-6)
- [14] Higgs ES, Dubey SA, Collier BAG, Simon JK, Bollinger L, Sorenson RA, et al. Accelerating vaccine development during the 2013–2016 West African ebola virus disease outbreak. *Curr Top Microbiol Immunol* [Internet]. 2017 [cited 2023 Sep 27]; 411: 229–61. Available from: https://link.springer.com/chapter/10.1007/82_2017_53
- [15] Raphaële Deraspe, Brian Hermon. Ebola Virus Disease: Outbreaks, Vaccines and Key Lessons [Internet]. 2021 [cited 2023 Sep 30]. Available from: <https://hillnotes.ca/2021/11/12/ebola-virus-disease-outbreaks-vaccines-and-key-lessons/>
- [16] Tomori O, Kolawole MO. Ebola virus disease: current vaccine solutions. *Curr Opin Immunol* [Internet]. 2021 [cited 2023 Sep 23]; 71: 27–33. Available from: <https://doi.org/10.1016/j.coi.2021.03.008>
- [17] Rodó X, San-José A, Kirchgatter K, López L. The need for a new strategy for Ebola vaccination. *Nature Medicine* 2021 27: 4 [Internet]. 2021 Apr 5 [cited 2023 Sep 23]; 27(4): 580–1. Available from: <https://www.nature.com/articles/s41591-021-01313-w>
- [18] Ajelli M, Merler S, Fumanelli L, Pastore y Piontti A, Dean NE, Longini IM, et al. Spatiotemporal dynamics of the Ebola epidemic in Guinea and implications for vaccination and disease elimination: A computational modeling analysis. *BMC Med* [Internet]. 2016 Sep 7 [cited 2023 Sep 25]; 14(1): 1–10. Available from: <https://bmcmmedicine.biomedcentral.com/articles/10.1186/s12916-016-0678-3>
- [19] Doshi RH, Fleming M, Mukoka AK, Carter RJ, Hyde TB, Choi M, et al. Vaccination of contacts of Ebola virus disease survivors to prevent further transmission. *Lancet Glob Health* [Internet]. 2020 Dec 1 [cited 2023 Sep 25]; 8(12): e1455–6. Available from: <http://www.thelancet.com/article/S2214109X2030454X/fulltext>
- [20] WHO. Second Ebola vaccine to complement "ring vaccination" given green light in DRC [Internet]. 2019 [cited 2023 Oct 3]. Available from: <https://www.who.int/news/item/23-09-2019-second-ebola-vaccine-to-complement-ring-vaccination-given-green-light-in-drc>
- [21] Abdul-Rahman T, Lawal L, Meale E, Ajetunmobi OA, Toluwalashe S, Alao UH, et al. Inequitable access to Ebola vaccines and the resurgence of Ebola in Africa: A state of arts review. *J Med Virol* [Internet]. 2023 Aug 1 [cited 2023 Sep 27]; 95(8): e28986. Available from: <https://onlinelibrary.wiley.com/doi/full/10.1002/jmv.28986>
- [22] Moon S, Sridhar D, Pate MA, Jha AK, Clinton C, Delaunay S, et al. Will Ebola change the game? Ten essential reforms before the next pandemic. The report of the Harvard-LSHTM Independent Panel on the Global Response to Ebola. *thelancet.com* [Internet]. 2015 [cited 2023 Sep 30]; 386: 2204–25. Available from: <http://dx.doi.org/10.1016/>

- [23] Buseh AG, Stevens PE, Bromberg M, Kelber ST. The Ebola epidemic in West Africa: challenges, opportunities, and policy priority areas. *Nurs Outlook*. 2015 Jan-Feb; 63(1): 30-40. <https://doi.org/10.1016/j.outlook.2014.12.013>. Epub 2014 Dec 17. PMID: 25645480; PMCID: PMC7111626.
- [24] WHO. UNICEF, WHO, IFRC and MSF announce the establishment of a global Ebola vaccine stockpile [Internet]. 2021 [cited 2023 Sep 24]. Available from: <https://www.who.int/news/item/12-01-2021-unicef-who-ifrc-and-msf-announce-the-establishment-of-a-global-ebola-vaccine-stockpile>
- [25] Doshi RH, Garbern SC, Kulkarni S, Perera SM, Fleming MK, Muhayangabo RF, et al. Ebola vaccine uptake and attitudes among healthcare workers in North Kivu, Democratic Republic of the Congo, 2021. *Front Public Health* [Internet]. 2023 Jul 25 [cited 2023 Sep 25]; 11: 1080700. Available from: <https://www.frontiersin.org/articles/10.3389/fpubh.2023.1080700/full>
- [26] Folayan MO, Yakubu A, Haire B, Peterson K. Ebola vaccine development plan: Ethics, concerns and proposed measures. *BMC Med Ethics* [Internet]. 2016 Feb 8 [cited 2023 Sep 22]; 17(1): 1–8. Available from: <https://bmcmedethics.biomedcentral.com/articles/10.1186/s12910-016-0094-4>
- [27] Marzi A, Mire CE. Current Ebola Virus Vaccine Progress. *BioDrugs* [Internet]. 2019 Feb 1 [cited 2023 Sep 23]; 33(1): 9–14. Available from: <https://link.springer.com/article/10.1007/s40259-018-0329-7>
- [28] Woolsey C, Geisbert TW. Current state of Ebola virus vaccines: A snapshot. *PLoS Pathog*. 2021 Dec 9; 17(12): e1010078. <https://doi.org/10.1371/journal.ppat.1010078>. PMID: 34882741; PMCID: PMC8659338.
- [29] Coltart CEM, Lindsey B, Ghinai I, Johnson AM, Heymann DL. The Ebola outbreak, 2013–2016: old lessons for new epidemics. *Philosophical Transactions of the Royal Society B: Biological Sciences* [Internet]. 2017 May 26 [cited 2023 Sep 27]; 372(1721): 2013–6. Available from: <https://royalsocietypublishing.org/doi/10.1098/rstb.2016.0297>