https://doi.org/10.1038/s41591-024-03295-x

How to prepare for the next inevitable Ebola outbreak: lessons from West Africa

Henry Kyobe Bosa, Neema Kamara, Merawi Aragaw, Misaki Wayengera, Patrick D. M. C. Katoto, Chikwe Ihekweazu, Mosoka P. Fallah, Moussa Douno, Robert Kwame Agyarko, Placide Mbala, Mamadou Souncalo Traoré, Ambrose Talisuna, James Bangura, Henry G. Mwebesa, Abdoulaye Bousso, Obasanya Joshua, James Sylvester Squire, Tolbert Nyenswah, Thelma V. Nelson, Justin Maeda, Olushayo Oluseun Olu, Yonas Tegegn Woldemariam, Benjamin Djoudalbaye, Alain Ngashi Ngongo, Tajudeen Raji, Francis Chisaka Kasolo, Ibrahima Socé Fall, Ahmed Ouma Ogwell, Jane Ruth Aceng & Jean Kaseya

Check for updates

Many lessons have been learned 10 years after the Ebola virus disease outbreak in West Africa, but urgent work is now needed to prevent another outbreak.

The West African Ebola virus disease (EVD) outbreak in 2014 emerged in a region in Africa that had previously not reported any EVD outbreak[1,2]. Subsequently, the outbreak rapidly spread and was protracted in the three Mano River basin countries (Guinea, Sierra Leone and Liberia)[3], with spillover cases in Nigeria, Senegal and Mali and, for the first time, importation into Europe and the USA[4,5]. It became the most extensive and protracted EVD outbreak in history, followed by the 2018 outbreak in the Democratic Republic of the Congo (DRC)[3]. For the first time, cases were reported in urban centers, underscoring the urban spread of the disease. Its devastation had a far-reaching impact on lives in the three largely affected countries for years to follow[6]. A total of 28,616 cases and 11,310 deaths were reported from Guinea, Sierra Leone and Liberia, with an additional 36 cases reported from Italy, Mali, Nigeria, Senegal, Spain, the UK and the USA[4].

Five years later, in 2021, Guinea experienced another outbreak that was controlled swiftly, much the same way as in Uganda in 2022 (refs. 7,8). The DRC, which had the largest number of EVD cases and deaths, experienced a protracted outbreak in 2018–2020 and another episode in 2021, despite the country's decades-long experience with EVD outbreaks[9]. In this historical context, we propose a strategic overhaul of intervention methodologies, emphasizing the need for a more adaptive and globally integrated approach to health crisis management. This revised strategy must account for the complexities introduced by rapid urbanization and the intricate web of international travel, and recognize the critical importance of global cooperation and innovation in health emergency readiness and response.

The genetic conservation of the Ebola viruses and their actual source, natural reservoirs and wildlife-to-human spillover dynamics remain elusive, which makes the prediction and prevention of EVD more challenging. However, since its first detection in 1976, the virus has not undergone any major selected mutations[10,11]. This presents an opportunity for sustained investment in and development of vaccines, therapeutics and diagnostics that remains on course. A key lesson from the EVD outbreak in West Africa is that in addition to weaknesses in health systems and other challenges highlighted in Table 1, slow and unpredictable funding was a major contributing factor to the inability to respond to the initial outbreaks rapidly. If the response to EVD had been effectively initiated just 2 months earlier, this could have averted fatalities by up to 80% in Sierra Leone and Liberia.

Recently, there has been an increase in the use of robust genomic surveillance techniques and big data to link and characterize EVD transmission dynamics and understand the evolution of viruses, in part because of advances during COVID-19. In the past, few diseases (such as influenza, measles, poliomyelitis and tuberculosis) or antimicrobial resistance were studied with this technology.

The advancement of vaccines against Ebola virus has been remarkable, albeit not for all strains. Approved field diagnostic tests and two vaccines against EVD are available, and two therapeutic candidates are in clinical trials[12].

Clinical outcomes have improved because of better understanding of Ebola virus pathogenesis and increased investment in the management of sepsis[13]. Most patients with EVD exhibit a degree of sepsis and altered hemodynamics, as well as renal insufficiency for patients with poor clinical outcomes. There is also growing understanding of new complexities in the immunological characteristics of those who survive EVD[14]. Emerging evidence shows long-term protection against infections with the same strain of Ebola virus and long-lasting severe immunological dysfunction in those who survive EVD[15].

Regional collaboration and advanced technologies

A network of regional laboratories should be established to enhance public health intelligence surveillance. Conducting regular, integrated, comprehensive assessments of epidemic intelligence and risk, including forecasting through innovative tools such as modeling, is vital for understanding the ecological dynamics and interactions between environmental ecosystems and human populations. Such efforts should elucidate the complex relationships and risk factors that contribute to disease emergence and spread, which will facilitate targeted interventions in high-risk communities.

This approach necessitates deliberate investment in readiness initiatives that encompass regular serological surveys, community awareness and sensitization programs, training of those in primary healthcare units and stockpiling of medical countermeasures and infection-prevention supplies. A collaborative regional network can harness collective resources, knowledge and technologies and thereby enhance the efficiency and effectiveness of epidemic surveillance, analysis and response across the continent. Integrating artificial

Table 1 | Challenges in mitigating the effects of EVD outbreaks

Challenge	Details	Solutions
Urban spread	Factors such as population density, slums, poverty, and inadequate health resources affect the dynamics of outbreaks, contact networks, and the effectiveness of interventions	Execute an over-reactive response and rapid containment of the disease at its source before it spreads to cities
Outbreak detection	Reliance on insensitive clinical markers and late signals such as hemorrhagic manifestations and clustered community deaths	Develop multiplex diagnostic kits for febrile illnesses and new, simple digital tools, and biomarkers such as platelet count
Burial practices	Continue to be the biggest driver of transmission, but vary across Africa	Commission studies to understand risky burial behaviors and the means to mitigate them
Medical countermeasures	Access is suboptimal, which results in a lack of POC diagnostics, limited or no vaccine for all strains, and an insufficient therapeutic stockpile	Support research and development technology transfer, and local manufacture of life-saving commodities in Africa
Cost of nonpharmaceutical interventions	Quarantine, isolation and contact tracing have economic and social costs, which can harm community engagement and compliance, and lead to skepticism, stigma, discrimination and attacks on healthcare workers	Develop tailored and culturally sensitive messages and public health practices; better preparedness; and early detection and response capacities to prevent, mitigate and rapidly contain diseases
Siloed working	Human, environmental, and animal health scientists continue to work in silos, despite the One Health concept, which emphasizes the multidisciplinary approach to combating zoonotic diseases	Strengthen collaboration, cooperation, coordination and communication among animal, human and environmental health, as well as between modern and traditional health workers, to achieve comprehensive and sustained mitigation measures
Slow and unpredictable funding	Public health programs, including emergency preparedness and response systems, and resilient district health systems are underfinanced across African countries	Prioritize the Abuja Declaration target of allocating 15% of the national budget to health; innovative emergency financing mechanisms such as the Africa Epidemic Fund and the risk insurance initiative by African Risk Capacity can access funding early in an outbreak
Suboptimal utilization of national and international health security plans	National health security plans have remained largely underfunded and rarely integrated with the After-Action Reviews and Simulation Exercises	Improve compliance with international and national health security plans, including resource mapping; institutionalize implantation of the National Action Plan for Health Security, tracking and accountability mechanisms across all stakeholders and governments
Limited POC diagnostics and bedside patient monitoring tools and equipment	Critical life support, including renal dialysis for patients who need it, has never been available in any African outbreak	Establish optimal care and treatment protocols and create capacitates and skill sets that can be rolled out in outbreak settings; establish partnerships and collaboration for setting up such care and treatment facilities
Inequitable access to vaccines	Cost and geography contribute to limited accessibility of vaccines	Invest in research and development, technology transfer and local manufacturing of lifesaving commodities in Africa; promote pool procurement mechanisms for better price and market shaping; improve logistics and cold-chain environments at service delivery points
Weak regulatory processes	Limited data to drive regulatory approval, particularly for Sudan Ebola virus and Marburg viruses; slow regulatory processes for product verification and authorization for emergency use; and slow clinical trial processes	Establish clear regulatory approval policies and frameworks to allow emergency use authorization to curtail transmission during pandemics and emergencies, including regional authorization mechanisms and endorsement of approvals of other stringent regulatory authorities
Long-term viral shedding	Survivors can harbor the virus for a long time in immunologically privileged sites, such as testes	Explore emerging advances in immune biotechnology to research and develop therapeutic medical countermeasures
Survivor stigma	Communities are not ready to accept survivors of EVD back into their social networks	Establish culturally sensitive risk communication and community engagements strategies, set up social support mechanisms and develop strategies to integrate survivors back into the community and ensure they receive adequate psychosocial support
Myths and misconceptions	Misinformation about the cause and cure of EVD	Develop strategies to manage 'infodemics' and build trust in communities

intelligence can further refine forecasting accuracy and optimize resource allocation for more-effective and timely interventions against emerging health threats (Table 2).

A health emergency preparedness, response and resilience framework

The World Health Organization has proposed ten pillars for strengthening health emergency preparedness, response and resilience, and has presented a strategic framework that can be effectively adapted for managing EVD outbreaks. This framework advocates for robust governance through the establishment of global health emergency councils, enhanced systems for rapid and coordinated response teams and strengthened surveillance networks. It underscores the necessity of innovative financing mechanisms to ensure readiness and swift action.

Aligning the management of EVD outbreaks with these pillars can deliver a more inclusive, equitable and coherent response to health emergencies. This approach can also integrate lessons learned from EVD into global health strategies, so that preparedness and response

Table 2 | Health technology required for EVD outbreak management

Technology investment	Description	Desired outcomes
Digitization and electronic tools for improved surveillance, case management and logistics management	Invest in soft and hardware deployment for real-time data collection, reporting, data analysis and automated sharing; improve clinical care and patient monitoring and logistics information management systems	Improved timeliness and completeness of data for real-time information sharing, analysis and dissemination to inform decision-making and resource allocation
Artificial intelligence	Pre-outbreak design of computer-powered technologies to enhance data mining, curating, integration and warehousing, and for improved (including predictive) analytics	Support of mining and integration of data from different sources, including non-health-sector data for health; triangulation and improved analytics; support of emergency preparedness and decision-making in prioritization and resource optimization for preparedness actions; forecasting of likely scenarios and plausible options for response
Genomic surveillance	Expand pathogen and host genomics sequencing, bioinformatics analysis and interpretation capacities at all levels	Monitoring of viral evolution; cluster detection to inform transmission dynamics; support of research and development of diagnostics and other medical countermeasures
POC diagnostics and bedside clinical monitoring tools and equipment	Medical diagnostics at service delivery point and optimal care and treatment for patients with critical life-support needs	Short diagnostics turnaround time for clinical decisions; optimal and quality service to reduce fatality rate, including quick recovery with minimal sequelae

systems are adaptable, well financed and capable of addressing the multifaceted challenges of future outbreaks. All countries and regions must be included in this, to ensure equity.

Domestic funding

National governments and regional institutions must fund their own preparedness and response needs. These could include contingency funding for preparedness and innovative financing mechanisms such as the African Epidemic Fund (an African Union initiative) and the World Bank pandemic fund, as well as the capacity building and parametric insurance introduced by the African Risk Capacity to support readiness and early response capabilities. Mechanisms can be combined, including sovereign insurance payouts and domestic health insurance mechanisms, so that epidemic response and preparedness funds are readily accessible for response and preparedness needs.

Alignment of global health funding mechanisms

The Global Alliance for Vaccines and Immunization, the US President's Emergency Plan for AIDS Relief, the Global Fund and national domestic funds should be aligned for systematic financing of the National Action Plan for Health Security, which has remained unfunded. There is a window of opportunity for countries to obtain more funds for preparedness and response through the Pandemic Fund, which allows countries to clearly define gaps and investment needs and build strong accountability and reporting systems for accessing financial resources.

Source of the virus reservoir and spillovers

Each country should establish or reactivate a coordinated 'One Health' framework to broaden and delve into ecological studies, test potential hypotheses and identify factors, patterns or epidemiological pathways to understand the emergence of Ebola virus, including its natural reservoirs.

Historically, animal, human and wildlife scientists have worked separately from each other; a nexus of collaboration and action is needed to bridge these divides and cultivate a collaborative environment. This approach will enable a comprehensive understanding of the triggers of the outbreaks and the design of prevention and control programs for the effective management of the disease across all relevant sectors.

BOX 1

Major changes to the global health security architecture

After the 2013–2016 EVD outbreak in West Africa, major reviews and improvements were made in the global health security architecture.

- Introduction of new frameworks in the IHR 2005 Monitoring and Evaluation Framework since 2015, including Joint External Evaluations, After Action Reviews, Simulation Exercises and the National Action Plan for Health Security
- Launch of a Global Health Security Agenda initiative in 2014 with financial support from global partners, including the USA and the 2015 G7 Summit
- Establishment of the Africa Centres for Disease Control and Prevention in 2016
- Reforms of the World Health Organization's health emergency operations and an increase in human and financial resources for emergency preparedness and response
- Establishment of Public Health Emergency Operation Centres and National Public Health Institutes in some countries

Universal point-of-care solutions

Enhancing the early detection and management of Ebola virus and other filoviruses will require detection markers and multiplex diagnostic tools for early identification and to increase diagnostic capabilities for a broader range of febrile illnesses. This approach should include automated diagnostic machines and the use of routine and novel diagnostic markers, such as altered platelet levels, white blood cells, liver function tests and renal function tests at the outbreak's onset, alongside innovative screening markers during the intra-epidemic phase to inform the development of point-of-care (POC) diagnostics.

POC diagnostics can provide rapid and accurate results that enable informed decision-making for the care and treatment of patients with EVD. More research is needed into universal POC diagnostics, therapeutics and vaccines effective against all filovirus species, akin to the

current efforts for pan-filovirus antigen rapid diagnostic tests. Addressing equitable access and affordability of these tools is crucial; low-cost technologies and manufacturing platforms, such as those established for the Cuban subunit protein vaccines against COVID-19 (Soberana and Abdala), can address access gaps.

Clinical trial design

Clinical trials of therapeutics and vaccines are often delayed or cancelled during outbreaks because of long regulatory and ethical approval processes and limited time for trial preparation. We advocate for the establishment of a joint multi-country platform, which would facilitate adaptive pre-approved trial protocols for various candidate therapeutics and new vaccines, enabling swifter movement from trial phases to application.

In the 10 years since the West African EVD outbreak, much has been done to mitigate the impact and consequences of Ebola virus (Box 1). Despite this, much remains undone. As Africa reflects on this outbreak, we should say 'never again' to an outbreak of a magnitude never anticipated and in a setting in which EVD had never before occurred.

Henry Kyobe Bosa[1], Neema Kamara[2], Merawi Aragaw[2] ✉, Misaki Wayengera[1], Patrick D. M. C. Katoto[3], Chikwe Ihekweazu[4], Mosoka P. Fallah[2], Moussa Douno[5], Robert Kwame Agyarko[6], Placide Mbala[7], Mamadou Souncalo Traoré[8], Ambrose Talisuna[9], James Bangura[10], Henry G. Mwebesa[1], Abdoulaye Bousso[11], Obasanya Joshua[12], James Sylvester Squire[13], Tolbert Nyenswah[14], Thelma V. Nelson[15], Justin Maeda[2], Olushayo Oluseun Olu[9], Yonas Tegegn Woldemariam[16], Benjamin Djoudalbaye[2], Alain Ngashi Ngongo[2], Tajudeen Raji[2], Francis Chisaka Kasolo[9], Ibrahima Socé Fall[17], Ahmed Ouma Ogwell[2], Jane Ruth Aceng[1] & Jean Kaseya[2]

[1]Ministry of Health, Kampala, Uganda. [2]Africa Centres for Disease Control and Prevention, Addis Ababa, Ethiopia. [3]Catholic University of Bukavu, Bukavu, Democratic Republic of the Congo. [4]WHO Hub for Pandemic and Epidemic Intelligence, Berlin, Germany. [5]Université Gamal Abdel de Conakry, Conakry, Guinea. [6]African Risk Capacity, Johannesburg, South Africa. [7]Institut National de Recherche Biomédicale, Kinshasa, Democratic Republic of the Congo. [8]National Institute for Research in Public Health, Bamako, Mali. [9]World Health Organization Regional Office for Africa, Brazzaville, Republic of Congo. [10]Health and Development in Action, Freetown, Sierra Leone. [11]Independent Consultant, Dakar, Senegal. [12]Consultant on Health Security, Abuja, Nigeria. [13]National Public Health Agency, Freetown, Sierra Leone. [14]Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA. [15]National Public Health Institute, Monrovia, Liberia. [16]World Health Organization Country office, Kampala, Uganda. [17]World Health Organization, Geneva, Switzerland.

✉e-mail: merawia@africacdc.org

Published online: 17 October 2024

References

1. Baize, S. et al. *N. Engl. J. Med.* **371**, 1418–1425 (2014).
2. Gire, S. K. et al. *Science* **345**, 1369–1372 (2014).
3. Aruna, A. et al. *MMWR Morb. Mortal. Wkly. Rep.* **68**, 1162–1165 (2019).
4. Zinszer, K., Morrison, K., Anema, A., Majumder, M. S. & Brownstein, J. S. *Lancet Infect. Dis.* **15**, 1005–1007 (2015).
5. WHO Ebola Response Team. *N. Engl. J. Med.* **375**, 587–596 (2016).
6. Onyekuru, N. A., Ihemezie, E. J., Ezea, C. P., Apeh, C. C. & Onyekuru, B. O. *Sci. Afr.* **19**, e01513 (2023).
7. Pare, B. C. et al. *South Afr. J. Infect. Dis.* **38**, 454 (2023).
8. Aceng, J. R. et al. *J. Public Health Afr.* **14**, 2735 (2023).
9. Rugarabamu, S. et al. *BMJ Glob. Health* **5**, e001955 (2020).
10. Balinandi, S. et al. *J. Virol.* **97**, e00590-23 (2023).
11. Alexander, K. A. et al. *PLoS Negl. Trop. Dis.* **9**, e0003652 (2015).
12. Crozier, I. et al. *Vaccines* **10**, 1213 (2022).
13. Jacob, S. T. et al. *Nat. Rev. Dis. Primers* **6**, 13 (2020).
14. Jain, S., Khaiboullina, S. F. & Baranwal, M. *Pathogens* **9**, 850 (2020).
15. Wiedemann, A. et al. *Nat. Commun.* **11**, 3730 (2020).

Competing interests

The authors declare no competing interests.