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The 2014-2016 Ebola virus outbreak in West Africa: epidemiological dynamics, determinants, and public health implications

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Abstract
Ebola Virus Disease (EVD) is a highly contagious and often fatal illness caused by the Ebola virus, first identified in 1976 in the Democratic Republic of Congo. Characterized by sudden fever, vomiting, hemorrhagic symptoms, and organ failure, EVD has become one of the most feared infectious diseases, particularly in sub-Saharan Africa. Over the years, Ebola outbreaks have posed significant challenges to public health systems, with the 2014-2016 West African epidemic marking the largest and most devastating in history. In addition to the virus's zoonotic origins, human-to-human transmission through bodily fluids has contributed to the rapid spread in affected regions, making control efforts complex. Recent advances in diagnostics, treatment, and vaccination, particularly the rVSV-ZEBOV vaccine, have revolutionized the response to Ebola outbreaks, significantly improving survival rates and containment strategies.

In parallel with Ebola, the global impact of the COVID-19 pandemic has highlighted the importance of coordinated international responses to emerging infectious diseases. The review of both Ebola and coronavirus infections emphasizes the lessons learned from the COVID-19 crisis, such as the need for swift mobilization of resources, public trust, and effective communication strategies, as crucial elements for tackling future Ebola outbreaks. The development of novel therapeutics, the importance of robust surveillance systems, and the engagement of local communities in health interventions are key components discussed. The review concludes with a call for sustained investment in global health systems, research, and cross-border collaboration to better prepare for and mitigate the impact of future infectious disease threats.

Keywords: Ebola virus outbreak, determinants, lessons learned, COVID-19 infection, West Africa

Introduction

Ebola Virus Disease (EVD), formerly referred to as Ebola haemorrhagic fever, is a severe and often fatal zoonotic disease caused by viruses of the genus *Ebolavirus*, family *Filoviridae* [1]. The virus is characterized by its filamentous shape and its ability to cause the sudden onset of fever, muscle pain, vomiting, diarrhea, and in severe cases, internal and external bleeding [2]. Transmission occurs through direct contact with blood, secretions, organs, or other bodily fluids of infected individuals or animals, as well as through surfaces contaminated with such fluids [3]. Fruit bats of the Pteropodidae family are considered the natural reservoir hosts, with occasional spillovers to humans and other primates triggering outbreaks.

The first documented outbreaks of EVD occurred in 1976, simultaneously in Nzara, Sudan, and Yambuku, Zaire (now the Democratic Republic of Congo), near the Ebola River, which lent the virus its name [4]. Over the subsequent decades, outbreaks were typically small, occurred in remote forested regions of Central Africa, and were rapidly contained. However, the 2014-2016 EVD outbreak in West Africa marked a turning point in the global understanding of the virus's epidemic potential. Beginning in Guinea in December 2013 and subsequently spreading to Liberia and Sierra Leone, the 2014-2016 outbreak was

unprecedented in scope, affecting densely populated urban areas and resulting in over 28,000 confirmed, probable, and suspected cases with more than 11,000 deaths [4]. It was also the first outbreak to be declared a Public Health Emergency of International Concern (PHEIC) by the WHO, revealing significant gaps in global epidemic preparedness and response systems [5].

Given the magnitude and complexity of the 2014-2016 Ebola outbreak, a comprehensive review is essential to consolidate current understanding of the virology and epidemiology of EVD, highlight the unique features of the West African epidemic, and extract lessons for future outbreak preparedness and response. Understanding the contextual, biological, and systemic factors that drove the outbreak will aid policymakers, researchers, and global health practitioners in designing more effective surveillance, containment, and response strategies for future public health emergencies.

Transmission Dynamics, Clinical Features, and Diagnosis of Ebola Virus Infection

Ebola Virus Disease (EVD) is primarily a zoonotic infection, with fruit bats of the *Pteropodidae* family considered the most likely natural reservoir. Spillover events to humans typically occur through direct contact with infected wild animals such as bats, non-human primates, and forest antelopes, often during hunting or handling of bushmeat [6]. These initial zoonotic transmissions mark the beginning of outbreaks, which are subsequently sustained by human-to-human transmission. Once the virus enters the human population, it spreads primarily through direct contact with the blood, secretions, organs, or other bodily fluids of infected individuals. Transmission also occurs through contact with surfaces and materials contaminated with these fluids. Importantly, sexual transmission has been documented due to the persistence of the virus in seminal fluid for months after clinical recovery, raising significant concerns for post-recovery transmission [7, 8]. Breastfeeding by infected mothers may also pose a risk, although the extent of viral shedding in breast milk remains under investigation [9]. Traditional burial practices involving washing and close contact with the deceased significantly contributed to the propagation of the virus during the 2014-2016 West African outbreak [10].

The clinical presentation of EVD is often non-specific in the early stages, posing diagnostic challenges, especially in resource-limited settings. Symptoms typically appear 2 to 21 days after exposure and include the sudden onset of fever, fatigue, muscle pain, headache, and sore throat, followed by vomiting, diarrhea, rash, and in some cases, internal and external bleeding. These early symptoms mimic those of other endemic infectious diseases such as malaria, typhoid fever, and Lassa fever, complicating timely diagnosis and response.

Accurate diagnosis of EVD requires laboratory confirmation. The most widely used diagnostic tool is reverse transcriptase-polymerase chain reaction (RT-PCR), which detects viral RNA in blood or body fluids and is most effective during the acute phase of the disease [11]. Serological testing, including ELISA, can detect antibodies to the virus in later stages or post-recovery. Given the overlap in clinical features with other tropical diseases, differential diagnosis supported by robust laboratory systems is essential to avoid misdiagnosis and ensure appropriate case management and containment.

Epidemiology of the 2014-2016 Ebola Virus Disease Outbreak

The 2014-2016 Ebola Virus Disease (EVD) outbreak in West Africa was unprecedented in scale, duration, and geographic spread [12]. Unlike earlier, more contained outbreaks, this epidemic rapidly evolved into a regional health emergency, affecting densely populated urban centres and spanning multiple international borders. The outbreak began in December 2013 in the forested region of southeastern Guinea and subsequently spread to Liberia and Sierra Leone, countries with fragile health systems still recovering from years of civil conflict [13]. These three countries bore the brunt of the epidemic, though cases were also reported in Nigeria, Mali, and Senegal, as well as in countries outside Africa, including the United States, Spain, and the United Kingdom, due to international travel [4].

At the height of the epidemic, the World Health Organization (WHO) reported over 28,600 confirmed, probable, and suspected cases of EVD, with over 11,300 deaths, reflecting a case fatality rate (CFR) of approximately 40%; the CFR varied significantly across regions and over time, depending on access to care, availability of supportive treatment, and early case detection. Guinea reported a CFR of approximately 67%, Liberia 45%, and Sierra Leone 28%—disparities reflecting differences in health infrastructure and outbreak management strategies [14]. Age-specific analysis revealed that young adults aged 15-44 years accounted for the majority of cases, representing the most socially and economically active population group. Children under 15 and the elderly above 45 were less affected in terms of absolute case numbers but had higher CFRs, possibly due to weaker immunity and limited access to supportive care.

Temporal trends showed that the outbreak peaked at different times in the three most affected countries: Liberia experienced its peak in September 2014, Sierra Leone in November 2014, and Guinea in January 2015 [4]. Following international mobilization, including the deployment of thousands of healthcare workers and the establishment of Ebola treatment units, case incidence declined steadily in 2015, with WHO declaring the end of the outbreak in June 2016 [4]. Graphical illustrations, such as epidemic curves and geographic heat maps, have been instrumental in tracking the progression of the outbreak. These visuals highlighted the rapid escalation and eventual containment of EVD, underscoring the critical role of surveillance and real-time data in epidemic response.

Determinants of the Outbreak's Severity

The severity of the 2014-2016 Ebola Virus Disease (EVD) outbreak in West Africa can be better understood through the Dahlgren and Whitehead model of health determinants, which highlights multiple layers of influence on health outcomes [15]. This framework helps dissect how individual, social, environmental, and structural factors converged to exacerbate the epidemic's impact. At the individual level, biological factors such as age and sex influenced both exposure risk and outcomes. Young adults, particularly those aged 15-44, represented the most affected demographic, partly due to their social roles and mobility. Higher mortality was also noted in children and older adults due to weaker immune responses [16]. Lifestyle factors played a significant role in transmission dynamics. Practices such as unsafe sex, including contact with survivors who may still carry the virus in semen months after recovery,

contributed to persistent transmission chains [8]. Additionally, traditional burial customs, involving washing and touching of corpses, became potent sources of community transmission [17].

Social and community networks further shaped transmission patterns. In many affected communities, caregiving roles were largely fulfilled by family members, especially women, without protective equipment, heightening their risk. Cultural norms, such as close contact during illness and death, facilitated spread within households and social groups [18]. At the level of living and working conditions, factors such as overcrowded housing, inadequate water and sanitation infrastructure, and limited access to healthcare critically hindered containment. Health facilities were ill-equipped, leading to nosocomial transmission among patients and healthcare workers. Finally, broader socioeconomic, cultural, and environmental conditions amplified vulnerability. Widespread poverty, low literacy, and high population mobility, especially across porous borders, complicated surveillance and control [19]. In rural areas, bushmeat consumption, including fruit bats and primates—natural reservoirs of the Ebola virus—was a key factor in zoonotic spillover events [20]. Together, these determinants illustrate that the outbreak's severity was not solely a matter of virology but a complex interplay of behavioral, cultural, structural, and political factors, underscoring the need for multisectoral approaches to epidemic preparedness and response.

Health Systems, Governmental, and Socioeconomic Response

The unprecedented scale and devastation of the 2014-2016 Ebola Virus Disease (EVD) outbreak in West Africa were closely tied to deep-seated weaknesses in health systems and broader socioeconomic and political conditions. The affected countries—Guinea, Liberia, and Sierra Leone—had some of the world's most fragile health infrastructures, suffering from chronic underfunding, limited health workforce capacity, and poor access to essential medical supplies and services [21]. The delayed recognition of the outbreak and the lack of early warning systems significantly hindered a timely response. In Guinea, initial cases were misdiagnosed as cholera or Lassa fever, leading to missed opportunities for containment (Baize *et al*., 2014) [22]. National preparedness plans were either nonexistent or grossly inadequate, reflecting a broader neglect of epidemic preparedness in public health planning.

Health worker vulnerability further compounded the crisis. Over 800 healthcare workers were infected, with more than 500 deaths reported—many due to inadequate training, lack of personal protective equipment (PPE), and poor infection control measures in health facilities [23,24]. This not only reduced capacity but also eroded public trust in the health system, leading some to avoid seeking care. Socioeconomic conditions, especially poverty, internal migration, and rapid urbanization, contributed significantly to disease spread. Many communities lived in overcrowded conditions with poor sanitation, facilitating human-to-human transmission. Movement across borders and into urban centers like Monrovia and Freetown fueled the outbreak's exponential growth [25]. Additionally, low literacy and reliance on informal care systems hampered effective communication and behavior change strategies. The outbreak occurred in a region recently emerging from decades of civil conflict, particularly in Liberia and Sierra Leone, where war had destroyed health infrastructure and displaced populations. Post-conflict fragility, including trauma, mistrust of authorities, and limited governance capacity, hampered effective coordination and response efforts [26].

Political instability and weak governance structures further delayed decisive action. Governments were slow to mobilize resources and often lacked credibility among their populations, fueling rumors, resistance to public health interventions, and attacks on response teams [27]. These systemic issues, rooted in colonial legacies and prolonged underdevelopment, created fertile ground for the virus to spread unchecked until international intervention was mobilized. This intersection of health system fragility, poverty, conflict, and political instability highlights the need for resilient, inclusive, and well-governed health systems in epidemic-prone regions.

Prevention and Public Health Interventions

Effective control of Ebola Virus Disease (EVD) requires a multi-layered approach involving all levels of prevention-primary, secondary, and tertiary-coupled with strong public health systems and community engagement strategies. Primary prevention focuses on halting the zoonotic spillover of the virus from animal reservoirs to humans. This involves reducing high-risk interactions such as hunting and consumption of bushmeat, especially fruit bats and non-human primates, which are believed to be the natural reservoirs of the virus [28]. Health education on safe animal handling, improved sanitation, and environmental management is are essential strategy. Ecological surveillance also plays a vital role in early detection of animal outbreaks and risk mapping to prevent spillover [29].

Secondary prevention emphasizes early detection, isolation, and contact tracing. Prompt identification of symptomatic individuals and the establishment of isolation centers were pivotal in reducing transmission during the 2014-2016 outbreak [30]. Rapid diagnostic testing using RT-PCR allowed for confirmation of cases, while community-based surveillance facilitated timely alerts. Investments in laboratory capacity and field epidemiology training programs, such as the CDC-supported Field Epidemiology Training Program (FETP), have since strengthened regional response capacities [31]. Tertiary prevention involves reducing morbidity and mortality in infected individuals through supportive care, psychosocial support, and rehabilitation. During the outbreak, tertiary care was constrained by inadequate health infrastructure and limited access to intravenous fluids, oxygen, and other supportive interventions [32]. Survivors also faced long-term complications such as ocular sequelae and joint pain, necessitating follow-up care [33].

Public health professionals played a central role in coordinating responses, training healthcare workers, and implementing control measures. However, an effective response demanded intersectoral collaboration between health, education, transportation, and communication sectors to ensure comprehensive and sustainable interventions [34]. The complexity of EVD transmission, linked to socio-cultural practices and environmental conditions, highlights the necessity of a One Health approach, integrating human, animal, and environmental health disciplines. Culturally sensitive community engagement was critical. Resistance to public health messaging and fear of healthcare facilities contributed to hidden cases and unsafe practices. Traditional burial rituals, which involved direct contact with corpses,

accounted for significant transmission; engaging local leaders, traditional healers, and survivors helped bridge trust gaps, enabling acceptance of safe burial practices and treatment protocols [35].

Given EVD's cross-border nature, ecological and regional interventions-including harmonized surveillance, coordinated border health checks, and joint preparedness plans-were essential. The Mano River Union countries later adopted the Integrated Disease Surveillance and Response (IDSR) strategy to strengthen regional coordination [36].

Vaccine deployment has become a key preventive tool. The rVSV-ZEBOV vaccine demonstrated 100% efficacy in ring vaccination trials in Guinea [36] and has since been used in outbreaks in the Democratic Republic of Congo. However, logistical challenges, cold-chain requirements, and vaccine hesitancy have limited broader deployment in remote settings. Moreover, current vaccines are strain-specific and do not offer protection against all Ebola species. Overall, sustained investment in public health infrastructure, community engagement, and cross-border collaboration is essential for EVD prevention and control.

Ebola Virus Compared with Coronavirus Infection: A Contextual Comparison

The 2014-2016 West African Ebola Virus Disease (EVD) outbreak and the global COVID-19 pandemic caused by the novel coronavirus (SARS-CoV-2) are two of the most significant public health emergencies of the 21st century. While caused by entirely different pathogens, these outbreaks share common challenges and offer valuable comparative insights into epidemic preparedness, transmission dynamics, public health response, and global collaboration. Comparing these two diseases is justified not only by their devastating global and regional impacts but also by the opportunity to draw lessons that can shape future outbreak prevention and response strategies in fragile and well-resourced settings alike.

EVD is caused by a filovirus (*Ebolavirus*) with a high case fatality rate (averaging 50%, but varying between 25-90% in past outbreaks) and is transmitted primarily through direct contact with the bodily fluids of symptomatic individuals (WHO, 2023). In contrast, COVID-19, caused by a coronavirus (*SARS-CoV-2*), has a much lower case fatality rate (about 1-2% globally) but spreads more rapidly via respiratory droplets and aerosols, often through asymptomatic or pre-symptomatic individuals (CDC, 2022; WHO, 2022) [37,38]. The transmission dynamics sharply contrast: Ebola's transmission is easier to contain with appropriate infection control and isolation since it requires close physical contact, while COVID-19's airborne and fomite-based spread facilitated rapid, silent community transmission across borders. These differences account for the global spread of COVID-19, resulting in over 6.9 million deaths and 770 million reported cases globally, while the 2014-2016 Ebola outbreak was geographically contained but resulted in over 11,000 deaths in West Africa [39].

From a health systems perspective, both outbreaks exposed gaps in preparedness. The Ebola outbreak revealed weaknesses in surveillance, laboratory capacity, and trust in health authorities in fragile settings [40], while COVID-19 highlighted that even well-resourced systems can become overwhelmed without surge capacity, equitable health access, and coordinated response structures [41]. Both responses underscore the importance of community engagement and culturally sensitive messaging. In West Africa, resistance to Ebola interventions was fuelled by mistrust and cultural disconnects. Similarly, misinformation and vaccine hesitancy undermined COVID-19 control efforts globally; these challenges demonstrate that public health must be both technically sound and socially informed [42].

Global collaboration has improved since the Ebola crisis, as seen in the rapid development of COVID-19 vaccines and therapeutics through initiatives like COVAX and CEPI. Conversely, Ebola vaccine development, though successful with rVSV-ZEBOV, took longer due to limited commercial incentives and lack of prior investment [43]. While Ebola and COVID-19 differ in virology, transmission, and mortality, both highlight the urgent need for robust public health systems, timely evidence-based policy, and multidisciplinary global cooperation. Lessons learned from both outbreaks should guide future health emergency preparedness strategies, especially in bridging the equity gap between high-and low-income settings.

Lessons Learned and Future Directions for Preparedness and Complication Readiness

The 2014-2016 West African Ebola Virus Disease (EVD) outbreak revealed systemic failures in epidemic preparedness, highlighting the critical need for a multidisciplinary and multisectoral response to complex public health threats. The epidemic's scale and rapid spread demonstrated that medical interventions alone are insufficient. Effective control required collaboration across public health, clinical medicine, anthropology, security, logistics, and communication sectors [44]. Such cross-disciplinary synergy is now foundational in global response models, including the *One Health* framework, which integrates human, animal, and environmental health systems [45].

A major takeaway was the importance of strengthening surveillance systems and emergency preparedness before outbreaks occur. Weak health infrastructure, poor disease detection capabilities, and delayed reporting contributed to the late recognition of the Ebola outbreak. In response, countries have reinforced Integrated Disease Surveillance and Response (IDSR) strategies, with WHO supporting national core capacities under the International Health Regulations (IHR) [36]. Investment in real-time data collection, mobile diagnostics, and community-based alert mechanisms is key to early warning and response readiness. Equally crucial was the recognition of global partnerships and political will. The outbreak underscored how international solidarity, through the involvement of the WHO, CDC, MSF, and others, can dramatically change the course of epidemics when aligned with local leadership. Global initiatives like the Coalition for Epidemic Preparedness Innovations (CEPI) and Africa CDC are results of this momentum, aiming to improve vaccine development, regional response capacity, and equitable access [46].

However, translating global policy into practice in fragile and conflict-affected settings remains a significant barrier. Insecurity, displacement, and mistrust often hamper the implementation of health interventions. Effective responses require not only technical expertise but also culturally appropriate engagement, local capacity-building, and governance reforms tailored to specific contexts [47]. Central to sustainable progress is evidence-based research that informs policy and fills critical knowledge gaps. Operational

research, health systems studies, and community-based participatory research are essential to adapting interventions to local realities and ensuring accountability. Policymakers must prioritize funding for research that generates actionable insights, enabling context-sensitive, inclusive, and timely responses to future public health emergencies.

Conclusion

The 2014-2016 Ebola Virus Disease (EVD) outbreak in West Africa served as a sobering reminder of how swiftly a localized epidemic can escalate into a regional and global health emergency. Beyond the staggering human toll, it revealed deep fractures in health systems, emergency preparedness, and global solidarity, especially in resource-limited and fragile settings. This review has explored the virology, epidemiology, transmission dynamics, and systemic determinants that shaped the outbreak's severity, as well as the public health interventions and lessons learned. Importantly, it highlights the necessity of a coordinated, multidisciplinary response anchored in community engagement, cultural sensitivity, and political will. Comparing Ebola with the COVID-19 pandemic underscores shared vulnerabilities and reinforces the urgency for sustained investment in surveillance, research, health infrastructure, and inclusive policy. As emerging infectious diseases continue to threaten global health security, evidence-based research and cross-sectoral collaboration must drive the design of agile, equitable, and locally grounded preparedness strategies. Ultimately, the legacy of the West African Ebola outbreak should not merely be one of tragedy, but of transformation—fueling resilience, reinforcing health systems, and reaffirming the world's collective responsibility to protect vulnerable populations before, during, and beyond the next outbreak.

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