

Assessing Africa's readiness for Marburg virus outbreaks: A review of surveillance, response, and infrastructure needs

David B. Olawade^{a,b,c,d}, Navami Leena^e, Sandra Chinaza Fidelis^f,
Olaekan John Okesanya^{g,h,*}, Chibuike S. Alisi^a, Eghosasere Egbonⁱ, Augustus Osborne^j

^a Department of Allied and Public Health, School of Health, Sport and Bioscience, University of East London, London, United Kingdom

^b Department of Research and Innovation, Medway NHS Foundation Trust, Gillingham, ME7 5NY, United Kingdom

^c Department of Business, Management and Health, York St John University, London, E14 2BA, United Kingdom

^d Faculty of Health Sciences and Wellbeing, The University of Sunderland, Sunderland, SR1 3SD, United Kingdom

^e Faculty of Public Health and Healthcare Management, Westford University College, Sharjah, United Arab Emirates

^f School of Nursing and Midwifery, University of Central Lancashire, Preston Campus, United Kingdom

^g Department of Medical Laboratory Science, Neuropsychiatric Hospital, Aro, Abeokuta, Nigeria

^h Department of Public Health, Faculty of Medicine and Health Sciences, Hormuud University, Mogadishu, 204, Somalia

ⁱ Department of Tissue Engineering and Regenerative Medicine, Faculty of Life Science Engineering, FH Technikum, Vienna, Austria

^j Department of Biological Sciences, School of Environmental Sciences, Njala University, PMB, Freetown, Sierra Leone

ARTICLE INFO

Keywords:

Marburg virus disease
Africa
Epidemic preparedness
Public health
Outbreak response
Marburg virus

ABSTRACT

Marburg virus disease (MVD) poses a critical public health threat to Africa, with mortality rates ranging from 24 to 100% and limited treatment options. Recent outbreaks across multiple African countries highlight the continent's vulnerability to this deadly pathogen, necessitating comprehensive assessment of preparedness capabilities. This narrative review evaluated Africa's current readiness for MVD outbreaks by examining surveillance systems, healthcare infrastructure, response protocols, and identifying critical preparedness gaps. A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and Google Scholar. Search terms included "Marburg virus," "Africa," "outbreak," "preparedness," "surveillance," and "response." Additional sources from WHO, Africa CDC, and national health ministries were included. Data extraction focused on epidemiological characteristics, preparedness measures, challenges, and recommendations. Analysis revealed significant preparedness gaps including inadequate surveillance systems in high-risk regions, limited laboratory diagnostic capacity, insufficient healthcare infrastructure in remote areas, inconsistent funding mechanisms, and weak cross-border coordination. Cultural barriers, lack of community awareness, and absence of licensed vaccines further compound these challenges. While some improvements have emerged from Ebola outbreak experiences, MVD-specific protocols and biosafety requirements remain underdeveloped. Africa requires urgent, coordinated action to strengthen MVD preparedness through enhanced surveillance networks, healthcare capacity building, community engagement programs, regional cooperation frameworks, and accelerated vaccine development. A multi-faceted approach combining infrastructure investment, policy development, and sustained international collaboration is essential to prevent widespread epidemics and protect public health across the continent.

1. Introduction

Marburg virus (species *Orthomarburgvirus marburgense*, MARV) is a highly infectious pathogen known to cause severe hemorrhagic fever in humans.¹ The species *Orthomarburgvirus marburgense* contains two

viruses: Marburg virus and Ravn virus, both capable of causing severe disease in humans.² According to El-khamissy,³ Marburg virus is closely related to the structure and clinical effects of Ebola virus. Initially discovered in 1967, the virus belongs to the *Filoviridae* family.^{4,5} The virus took its name from Marburg, a German town where the first known

Peer review under the responsibility of Jiangsu Institute of Parasitic Diseases.

* Corresponding author. Department of Public Health, Faculty of Medicine and Health Sciences, Hormuud University, Mogadishu, 204, Somalia.

E-mail address: okesanyaolalekanjohn@gmail.com (O.J. Okesanya).

<https://doi.org/10.1016/j.dcit.2026.100092>

Received 26 September 2025; Received in revised form 29 December 2025; Accepted 11 September 2026

Available online 22 September 2026

2949-9240/© 2026 The Authors. Publishing services by Elsevier B.V. on behalf of KeAi Communications Co., Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

outbreak occurred.⁶ Since then, the virus has primarily emerged in Africa, where specific environmental and ecological conditions sustain its existence and pose ongoing risks for human exposure.⁷ Ravn virus, first identified during an outbreak in Democratic Republic of Congo in 1987, represents a distinct but closely related filovirus that can also cause fatal hemorrhagic fever, though it has been associated with fewer documented outbreaks compared to Marburg virus.⁸ Srivastava et al.⁹ argued that Marburg virus represents a severe public health threat, marked by a high mortality rate, no licensed treatments or vaccines, and a limited understanding of its transmission dynamics in human populations.

From a virological perspective, MARV belongs to the family Filoviridae, genus Marburgvirus, characterized by its filamentous, pleomorphic virion morphology typically measuring 80 nm in diameter and 790–1400 nm in length.¹⁰ The virus possesses a negative-sense, single-stranded RNA genome of approximately 19 kilobases encoding seven structural proteins: nucleoprotein (NP), virion proteins (VP35, VP40, VP30, VP24), glycoprotein (GP), and RNA-dependent RNA polymerase (L).¹⁰ The surface glycoprotein GP mediates viral entry into host cells and is the primary target for neutralizing antibodies, while VP24 and VP35 play critical roles in immune evasion by antagonizing host interferon responses.^{10,11} Genetic analysis has revealed distinct lineages within the species *Orthomarburgvirus marburgense*, including Marburg virus and Ravn virus, which exhibit nucleotide sequence divergence of approximately 21% and demonstrate varying degrees of virulence in human infections.¹² The virus's genetic diversity, combined with its capacity for rapid replication and strong immunosuppressive properties, contributes to the challenges in developing broadly effective diagnostics, vaccines, and therapeutics, while also influencing outbreak severity and transmission dynamics observed across different African regions.^{11,12}

The contemporary landscape of viral threats of animal origin has expanded considerably, with recent outbreaks demonstrating ongoing risks to global public health. The 2014–2016 Ebola virus outbreak in West Africa highlighted the devastating impact of viral hemorrhagic fevers, with the virus spreading through direct contact with bodily fluids and causing intermittent outbreaks across several African nations.¹³ Similarly, dengue virus outbreaks, including a novel lineage of DENV-2 identified in Vietnam in 2022, underscore the evolving nature of arboviral threats.¹⁴ The recent emergence of mpox (Clade Ib) has sparked renewed international concern, with the more virulent Clade I demonstrating increased potential for transmission and severe clinical outcomes.¹⁵ Oropouche virus, another re-emerging arbovirus, has caused outbreaks in border regions of western Amazon, affecting populations in areas with favorable environmental conditions for vector distribution.¹⁶ Additionally, the 2024 Zika virus outbreak in Pune, India, though caused by strains without microcephaly-linked mutations, demonstrated enhanced transmission capabilities and unique clinical presentations including thrombocytopenia and bleeding manifestations.¹⁷ Most recently, the discovery of HKU5-CoV lineage 2, a novel bat-infecting coronavirus with spillover potential to humans through its use of the ACE2 receptor, has raised emerging concerns about future zoonotic transmission events.¹⁸ These concurrent viral threats emphasize the critical importance of strengthening surveillance, preparedness, and response systems, particularly in regions like Africa where MVD continues to pose significant risks.

Wood et al.¹⁹ reported that Marburg virus is zoonotic, with its primary animal host demonstrated to be the African fruit bat, particularly the *Rousettus aegyptiacus* species, also known as the Egyptian fruit bat.^{20,21} While *Rousettus aegyptiacus* bats serve as the primary reservoir, other animals may contribute to zoonotic transmission. Although fruit bats remain the most documented natural host, surveillance efforts should consider potential involvement of other wildlife species in virus maintenance and spillover events, particularly in regions where human-animal contact is frequent.²² Human infection typically occurs after prolonged contact with bat habitats, such as caves and mines, where individuals are exposed to bat saliva, urine, or feces. Once a

human is infected, the virus can spread through direct contact with bodily fluids, including blood, saliva, sweat, and urine.²³ Additionally, Marburg virus can be transmitted through sexual contact, as the virus persists in testicular Sertoli cells and is released through seminal fluid for extended periods (in some cases exceeding 200 days post-infection), posing a risk primarily from men to their sexual partners, though women could theoretically contribute to sexual transmission as well.²⁴ Ofori & Nyarko²⁵ noted that secondary human-to-human transmission has been documented in healthcare settings, though evidence for transmission during traditional burial practices requires further investigation.²⁶ Symptoms of Marburg virus disease generally appear between 2 and 21 days after exposure, beginning with fever, chills, headache, and muscle pain.³ As the illness progresses, symptoms become more severe, including abdominal pain, nausea, vomiting, diarrhea, and chest pain.²⁷ In advanced stages, Goh & Singh²⁸ reported that MVD can cause hemorrhaging, though bleeding manifestations are less common than previously thought, like Ebola virus disease.²⁹ The case fatality rate (CFR) for MVD ranges from 24 to 100%, depending on the viral strain and the quality of medical care available,^{30,31} highlighting the need for strong public health measures.

Africa has been the most heavily affected region by past MVD outbreaks, with the continent bearing the primary burden of disease since the virus's discovery.⁷ Since its discovery, Marburg virus has sparked sporadic outbreaks across African nations, primarily in East and Central Africa.⁹ The first documented case in Africa was detected in a traveler in South Africa in 1975 who had been exposed in Zimbabwe.³² Subsequently, significant outbreaks have been reported in Democratic Republic of Congo (1998–2000),³³ Kenya (1980, 1987),⁴ Angola (2004–2005),³⁴ Uganda (2007, 2012, 2014, 2017),³⁵ Ghana (2022),³⁶ Equatorial Guinea (2023),³⁷ Tanzania (2023),³⁸ and Rwanda (2024).³⁹ The Angola outbreak in 2004–2005 stands as the deadliest recorded, with over 250 deaths and a case fatality rate exceeding 80%.³⁴ Recently, Tanzania experienced an outbreak in 2023 with 9 confirmed cases and 6 deaths, highlighting the continued threat across the continent.⁴⁰ The recurrent emergence of MVD outbreaks in Africa suggests it remains a persistent threat, especially in regions with limited healthcare infrastructure and proximity to natural bat reservoirs. Table 1 provides a comprehensive timeline of laboratory-confirmed MVD cases in Africa.

Due to its high mortality rate, ease of human transmission, and limited treatment options, Marburg virus poses a critical threat to public health in Africa. Given the virus's persistence in bat populations and its potential to spread among humans, a proactive approach to epidemic preparedness is essential. MVD outbreaks share similar transmission patterns and clinical presentations with Ebola virus disease, presenting comparable challenges in controlling spread in resource-limited settings.⁴⁹

However, critical differences between MVD and Ebola virus disease significantly impact prevention and control strategies.^{49,50} While both viruses belong to the Filoviridae family and share similar transmission routes through direct contact with bodily fluids, MVD exhibits distinct characteristics that require tailored approaches.⁵⁰ The incubation period for MVD ranges from 2 to 21 days, similar to Ebola, but human-to-human transmission efficiency may differ, with MVD demonstrating variable transmission rates across outbreaks (case fatality rates ranging from 24 to 88% compared to Ebola's more consistent 50–90%).^{51,52} A particularly important distinction is the lower frequency of hemorrhagic manifestations in MVD compared to Ebola virus disease.⁵³ This difference creates significant implications for clinical diagnosis, as healthcare providers may not immediately recognize MVD cases when hemorrhagic symptoms are absent, potentially leading to delayed diagnosis and increased nosocomial transmission.⁵⁰ This necessitates broader case screening criteria for MVD that do not rely solely on hemorrhagic presentation.

Furthermore, MVD's demonstrated persistence in immune-privileged sites (particularly in seminal fluid for over 200 days post-infection) requires extended sexual transmission prevention protocols beyond those

Table 1
Historical timeline of laboratory-confirmed cases of Marburg virus disease in Africa.

Year	Country	Cities	Origin	Fatality (deaths/ confirmed cases)	References
1975	South Africa	Johannesburg	Travel to Zimbabwe (Contact with infected bats in caves or visit to Sinoia caves)	1/3 (33%)	32
1980	Kenya	Nairobi	Proximity to Kitum Cave, Mount Elgon National Park	1/2 (50%)	41
1987	Kenya	Nairobi	Visits to Kitum caves and Mount Elgon National Park	1/1 (100%)	8
1998-2000	Democratic Republic of Congo	Durba and Watsa villages	Infection among gold miners in caves (including Goroubwa cave)	128/154 (83%)	33
2004-2005	Angola	Uige province	Unknown source	227/252 (90%)	34,42
2007	Uganda	Kamwenge district	Gold mining activity in Kitaka cave	1/4 (25%)	35
2012	Uganda	Kabale, Ibanda, Mbarara and Kampala	Contact with <i>Rousettus aegyptiacus</i> bats in caves	4/15 (27%)	43,44
2014	Uganda	Kampala	Unknown cause	1/1 (100%)	43,44
2017	Uganda	Kween	Familial cluster outbreak	3/4 (75%)	43,44
2021	Guinea	Gueckedou	Unknown cause	1/1 (100%)	45
2022	Ghana	Ashanti region	Familial cluster outbreak	2/3 (67%)	36
2023	Equatorial Guinea	Kie-Ntem, Centre Sur	Unknown	35/40 (88%)	37,46
2023	Tanzania	Bukoba district	Travel to Goziba Island in Lake Victoria	6/9 (67%)	37,38
2024	Rwanda	Kigali	Exposure to <i>Rousettus aegyptiacus</i> bats	15/66 (23%)	29,46
2025	Tanzania	Biharamulo and Muleba District, Kagera	Exposure to <i>Rousettus aegyptiacus</i> bats with connections to Rwanda (2024) outbreak	10/10 (100%)	47,48

typically employed for Ebola.²⁴ Additionally, the specific association of MVD outbreaks with cave and mine exposures to bat populations demands occupation-specific prevention strategies, including enhanced personal protective equipment protocols for miners and cave workers, which are not as central to Ebola prevention efforts.⁵³ These fundamental differences underscore why MVD-specific protocols, rather than adapted Ebola protocols, are essential for effective outbreak prevention and control.⁵⁰ Learning from past Ebola outbreaks has demonstrated the value of rapid response measures, community involvement, and robust healthcare systems to contain outbreaks effectively.

Marburg virus poses a severe and growing threat to African public health, with repeated outbreaks in several African countries underscoring the region's vulnerability. Despite the virus's high mortality rate and its potential for rapid human-to-human transmission, Africa's healthcare systems often lack the necessary infrastructure, resources, and trained personnel to contain such outbreaks effectively. The problem lies in the region's insufficient preparedness, which could lead to widespread transmission and significant loss of life if an epidemic occurs.

The rationale for this narrative review is to comprehensively assess Africa's current level of preparedness for Marburg virus by examining existing surveillance systems, healthcare capacity, public awareness, and response protocols. This review aims to inform stakeholders and public health policymakers on areas requiring urgent improvement by identifying critical gaps and highlighting the challenges faced in preventing an epidemic. The objective is to provide a holistic view of Africa's readiness to manage potential MVD outbreaks, offering recommendations to bolster preventative measures and mitigate the risks of a large-scale epidemic.

2. Methods

This narrative review was conducted using a comprehensive search strategy to identify relevant literature on Marburg virus disease preparedness in Africa. A systematic search was performed across multiple electronic databases including PubMed, Scopus, Web of Science, and Google Scholar from January 1967 to December 2024. Search terms included combinations of "Marburg virus," "Marburg virus disease," "MVD," "Africa," "outbreak," "preparedness," "surveillance," "response," "epidemic," and "public health." Additional sources were identified through reference lists of included studies and grey literature from international health organizations including the World Health Organization (WHO), Africa Centres for Disease Control and Prevention (Africa

CDC), and country-specific health ministry reports. Studies were included if they reported on Marburg virus outbreaks, preparedness measures, healthcare infrastructure, surveillance systems, or response activities in African countries. Articles in English were prioritized, though relevant studies in other languages with English abstracts were considered. Data extraction focused on epidemiological data, outbreak characteristics, preparedness measures, response activities, challenges, and recommendations. The narrative synthesis approach was employed to analyze and present the findings thematically.

3. Understanding the threat of Marburg virus in Africa epidemiology

Marburg virus's primary reservoir has been demonstrated to be the African fruit bat, particularly the *Rousettus aegyptiacus* or Egyptian fruit bat, which is widely found in parts of Africa and acts as an asymptomatic carrier.^{20,54} According to Chomel et al.,⁵⁵ human infections often occur through direct exposure to these bats' natural habitats, such as caves and mines, where people may encounter infected bat saliva, urine, or feces. Once a human is infected, the virus can spread from person to person through direct contact with bodily fluids, including blood, saliva, sweat, and urine.⁵ Srivastava⁵⁶ noted that transmission is especially problematic in healthcare environments with insufficient infection control measures and potentially during traditional burial practices, though specific evidence for the latter requires further documentation.⁵⁷ Alla et al.⁵⁸ reported that the incubation period for Marburg virus ranges from 2 to 21 days, after which initial symptoms, including fever, chills, and headache, appear. These symptoms often lead to severe abdominal pain, nausea, and in some cases bleeding, ultimately leading to multi-organ failure in severe cases. However, there are some differences between Marburg virus and Ebola virus; for example, Ebola outbreaks have tended to receive more international attention and funding, resulting in improved treatment and vaccine research.⁵⁷ Conversely, Marburg virus has not seen the same level of investment, leaving significant gaps in vaccine development and treatment options. These gaps in resources and support make MVD potentially more challenging to control in the event of an outbreak, as it would rely more heavily on early detection and containment measures.

Measures to reduce human-bat contact are critical for MVD prevention. These include education about avoiding caves and mines known to harbor infected bats, use of personal protective equipment for essential cave work, proper waste management to avoid attracting bats to human settlements, and implementation of bat exclusion measures in

buildings. Mining operations in areas with known bat populations require specific protocols including health monitoring, protective equipment, and regular health screenings for workers.^{59,60} Africa's socio-economic and environmental landscape significantly contributes to the spread risk of MVD.⁶¹ Rapid urbanization in several African countries has created densely populated areas where healthcare infrastructure may be inadequate to handle outbreaks. Additionally, the high mobility of populations due to economic migration, cross-border trade, and cultural events increases the likelihood of virus spread across regions. Many African countries also lack healthcare resources, making implementing rapid containment and response measures challenging. Climatic conditions further compound these risks; for example, high temperatures and humidity in some regions can affect the stability of pathogens, and seasonal changes can influence bat populations and their interactions with humans. Finally, Park²⁶ reported that traditional burial practices, common in many African cultures, involve direct contact with deceased individuals, though specific documentation of MVD transmission through these practices needs further investigation. These socio-economic, environmental, and climatic factors underscore the need for a strong, coordinated approach to surveillance, community engagement, and healthcare infrastructure to mitigate the threat of MVD epidemics. Table 2 provides an overview of MVD outbreaks across African countries, including deaths and confirmed cases.

In Table 2, Uganda has recorded the highest number of outbreaks in Africa, which occurred in clusters of those exposed to *Rousettus aegyptiacus* bats in caves and mines.⁴⁴ Infected individuals eventually spread the virus within their nuclear family settings. Overall, most sporadic cases or outbreaks in Africa are linked with exposure of index cases to caves and mines, which are usual habitats for infected bats.^{33,34,37} Possible cross-country spillover cases are also noted in Equatorial Guinea and Ghana with similar genetic composition of viruses in neighboring countries.^{36,37} As of October 14th, 2024, Rwanda reported 62 confirmed cases of MVD. The case fatality rate (CFR) was 24.2%, with 15 deaths recorded.⁶² Cases were detected in seven of Rwanda's 30 districts, including Gasabo, Gatsibo, Kamonyi, Kicukiro, Nyagatare, Nyarugenge, and Rubavu.⁶³ A high proportion of cases were healthcare workers, highlighting nosocomial transmission risks.⁶² Over 3797 tests were conducted by October 14, 2024, 21 individuals were in isolation and receiving treatment, while 26 had recovered.⁶³ The outbreak spread across multiple districts, raising concerns about potential intercommunal and cross-border transmission.⁶⁴

4. Africa's current level of preparedness

Africa's current surveillance systems for infectious diseases, including Marburg virus, have notable gaps, particularly in high-risk regions' early detection and laboratory diagnostic capacities.⁶⁵ Surveillance infrastructure has improved somewhat due to investments and lessons learned from the Ebola outbreaks, with many countries establishing basic frameworks for disease detection. However, surveillance capacities remain inconsistent across the continent. Some countries have implemented early warning systems and community-based surveillance to report unusual illness clusters, but many rural and remote areas still lack these systems, reducing early detection efficacy.⁶⁶ In recent years, the Africa Centres for Disease Control and Prevention (Africa CDC) have strengthened regional health networks by supporting cross-border surveillance initiatives.⁶⁷ Yet, reliable laboratory diagnostics for Marburg virus remain limited, often requiring samples to be sent to specialized labs outside the affected area or even the country, delaying confirmation and intervention. Enhanced laboratory networks with BSL-4 capabilities specifically for MARV diagnostics are essential, as the virus requires higher biosafety measures compared to many other pathogens.⁶⁸ Early detection and timely response to outbreaks are significantly hindered without reliable local diagnostic facilities.⁶⁶

As detailed in Table 3, regional comparison reveals distinct preparedness profiles across Africa. East African countries, particularly Uganda, have developed localized expertise through repeated outbreak experiences but continue to struggle with resource limitations and infrastructure gaps, especially in rural mining communities where exposure risk is highest.⁶⁹ Central Africa faces compounded challenges of political instability and challenging geography that hinder sustained preparedness investments, despite valuable experience from the prolonged DRC outbreak.⁷⁰ West Africa represents an emerging concern, as recent first-time outbreaks in Ghana and Equatorial Guinea expose critical gaps in MVD-specific knowledge and protocols, though these countries can leverage their Ebola outbreak experience.^{71,72} Southern Africa, while possessing stronger health infrastructure and laboratory capacity, lacks recent clinical experience with MVD, creating different preparedness needs focused on maintaining diagnostic readiness for potential imported cases.⁷⁰ These regional variations necessitate differentiated, context-specific preparedness strategies rather than uniform continental approaches.

4.1. Public health infrastructure

Public health infrastructure in Africa continues to face significant

Table 2
Overview of Marburg virus disease outbreaks across African countries.

Countries	Number of outbreaks and years	Deaths	Confirmed cases	Description of events	References
Angola	1 (2004-2005)	227	252	High fatality outbreak of unknown specific cause. Potential exposure to <i>Rousettus aegyptiacus</i> bat reservoirs and human-to-human spread	34,42
Democratic Republic of Congo	1 (1998-2000)	128	154	Fatal outbreak among gold miners exposed to <i>Rousettus aegyptiacus</i> bats in Goroumbwa caves	33
Equatorial Guinea	1 (2023)	35	40	Fatal outbreak of unknown causes in border regions, suggesting possible bat spillover from neighboring countries	37
Ghana	1 (2022)	2	3	Family outbreak with no known cave exposure history. Possible spillover from West African bats with similar genetic composition	36
Guinea	1 (2021)	1	1	Single fatal case of unknown origin. Potential bat exposure	45
Kenya	2 (1980; 1987)	2	3	Cases connected to <i>Rousettus aegyptiacus</i> bats in Kitum caves at Mount Elgon National Park	56,57
Rwanda	1 (2024)	15	66	Current outbreak linked to fruit bat exposure with human-to-human transmission complicating spread	39,46
South Africa	1 (1975)	1	3	Traveler contracted virus in Zimbabwe, infected companion and nurse who recovered	32
Tanzania	1 (2023)	6	9	Index case linked to Goziba Island visit with family and healthcare worker transmission	37,38
Uganda	4 (2007; 2012; 2014; 2017)	9	24	Cluster outbreaks associated with bat exposure in mining caves with family transmission	35,43,44

Table 3

Comparison of regional preparedness status for MVD in Africa.

Region	Representative Countries	Past Outbreak Experience	Economic Level & Health Investment	Primary Preparedness Challenges	Existing Strengths	Priority Needs	References
East Africa	Uganda, Kenya, Tanzania, Rwanda	High (Uganda: 4 outbreaks; Kenya: 2 outbreaks; Tanzania: 2 outbreak; Rwanda: 1 outbreak)	Low-to-middle income; variable health investment (Uganda ~7% GDP, Kenya ~5% GDP)	Infrastructure gaps in rural areas; limited BSL-4 lab capacity; high healthcare worker infection rates	Experience-based protocols from repeated outbreaks; established surveillance in high-risk mining/cave areas; community awareness in outbreak-prone districts	Strengthen BSL-4 laboratory networks; enhance PPE stockpiles; formalize regional coordination mechanisms; develop occupation-specific protocols for mining communities	11,47,69,73
Central Africa	Democratic Republic of Congo	Moderate (1 major outbreak: 1998-2000)	Low income; limited health infrastructure (DRC ~4% GDP on health)	Political instability; challenging terrain; weak healthcare infrastructure; limited diagnostic capacity; frequent population displacement	Experience from prolonged 1998-2000 outbreak; existing Ebola response frameworks adaptable to MVD	Establish decentralized diagnostic facilities; improve transportation infrastructure for rapid response; strengthen cross-border surveillance with neighboring countries	23,70
West Africa	Ghana, Guinea, Equatorial Guinea	Emerging (Ghana: 1 outbreak in 2022; Guinea: 1 case in 2021; Equatorial Guinea: 1 outbreak in 2023)	Mixed (Ghana: middle income ~4% GDP; Guinea/EG: low income ~3-5% GDP)	Limited MVD-specific experience; lack of established protocols; low public and healthcare worker awareness; potential for misdiagnosis due to unfamiliarity	Recent Ebola outbreak experience (Guinea); relatively stronger health systems in Ghana; established disease surveillance networks	Develop MVD-specific training programs; create culturally adapted community engagement strategies; establish rapid diagnostic capacity; improve healthcare worker protection protocols	70-72
Southern Africa	South Africa (historical case only)	Minimal (1 imported case in 1975)	Middle-to-high income; relatively stronger health systems (SA ~8% GDP on health)	Low clinical familiarity with MVD; limited bat habitat surveillance; potential for imported cases from endemic regions	Advanced laboratory capabilities; stronger healthcare infrastructure; better resourced health systems	Maintain diagnostic preparedness for imported cases; strengthen surveillance at points of entry; develop rapid response protocols despite low domestic risk	70,74

challenges, affecting the continent's ability to respond rapidly to MVD outbreaks.⁷⁵ While hospitals and healthcare facilities in urban areas are often better equipped, rural areas typically closer to high-risk bat habitats, face shortages in personnel, medical equipment, and resources for patient isolation and intensive care.⁷⁶ Few facilities are specifically equipped to handle hemorrhagic fevers, and those that exist are often overwhelmed by the demands of managing infectious diseases, especially during outbreaks.^{76,77} Rapid isolation of suspected cases is crucial for containing Marburg virus. Still, many facilities lack adequate isolation wards or personal protective equipment (PPE), creating potential vectors for in-hospital transmission.^{38,78} The 2022 Ghana outbreak revealed gaps in infrastructure as some facilities struggled to implement proper containment procedures promptly.^{78,79} Specific infrastructure requirements for MVD include BSL-4 laboratory capabilities, specialized isolation units with negative pressure systems, and enhanced PPE protocols that differ from standard Ebola preparations.⁸⁰ The current infrastructure is not universally sufficient to handle the demands of a large-scale outbreak, underscoring the need for expanded resources, staff training, and protective equipment to improve response capabilities.^{81,82}

4.2. Existing policies and guidelines

Specific policies and guidelines for managing MVD outbreaks are limited in many African countries despite regional efforts to strengthen infectious disease control frameworks.^{37,76} Policies are often adapted from Ebola virus disease response protocols, but differences in disease epidemiology, required biosafety levels, and bat exposure prevention necessitate MARV-specific strategies.⁸³ The World Health Organization (WHO) has provided guidance for MVD outbreak response, but national policies and procedures in many African countries are still under development.⁸⁴ Some nations have adopted general infectious disease frameworks that cover surveillance, contact tracing, and isolation procedures. Still, these protocols are not always enforced or adapted to rural

and high-risk settings where MVD is most likely to emerge.⁷⁵ The Africa CDC has developed initiatives to support countries in enhancing their outbreak response plans. Yet, the practical implementation of these guidelines is often limited by resource constraints, logistical challenges, and a lack of trained personnel.⁸⁵ Key policy differences for MVD include specific protocols for mining and cave work, enhanced laboratory biosafety requirements, and specialized training for healthcare workers on filovirus management.⁸⁶ Strengthening MVD-specific policies, supported by adequate funding and consistent implementation, is essential for improving preparedness.⁵⁶

4.3. Community engagement and awareness

Community engagement and public awareness are critical in preventing and controlling MVD outbreaks, but many African countries face challenges in effectively reaching vulnerable populations with accurate information.^{76,77} Public knowledge about Marburg virus is low compared to awareness of diseases like Ebola, leading to misconceptions and limited understanding of prevention measures.⁴⁰ Outreach programs vary by region, with some communities receiving regular health education initiatives, while others, particularly in remote areas, remain uninformed.⁸⁷ Recent efforts have focused on community education in high-risk regions, especially in areas with significant bat populations, to inform people about symptoms and precautions.⁴⁰ However, persistent mistrust in healthcare systems and traditional beliefs can hinder compliance with preventive measures and create resistance to isolation and treatment protocols.⁸⁸ The WHO and Africa CDC have supported campaigns to improve awareness, yet localized, culturally sensitive approaches are needed to increase community involvement and cooperation.⁸⁵

Successful community-based interventions demonstrate the effectiveness of culturally adapted strategies. In Uganda's Kween district following the 2017 outbreak, health authorities partnered with traditional leaders and local council members to deliver MVD prevention

messages through existing community structures.⁸⁹ Traditional leaders incorporated bat contact avoidance messaging into community gatherings, while utilizing local language radio broadcasts (in Kupsabiny and Sebei languages) to promote symptom recognition and early reporting.⁸⁹ This approach resulted in increased community cooperation with contact tracing efforts and reduced delays in seeking medical care.⁸⁹ Similarly, during Tanzania's 2023 outbreak response in Kagera region, health workers collaborated with religious leaders to address concerns about safe burial practices while respecting cultural traditions.⁶⁵ Community health workers, selected from local villages and trained in MVD prevention, conducted door-to-door education campaigns that emphasized practical measures such as avoiding caves where bats roost, using protective equipment for essential mining work, and recognizing early symptoms requiring immediate medical attention.^{90,91} These interventions demonstrated that when prevention messages are delivered by trusted community members in culturally appropriate contexts, compliance with public health measures significantly improves, highlighting the operability of culturally sensitive strategies beyond theoretical recommendations.

Effective community engagement, tailored to the cultural contexts of each region, will play an essential role in preventing the spread of MVD in Africa.⁶¹ Effective community-based MVD prevention in Africa relies on interconnected elements, as visualized in Fig. 1. This approach emphasizes cultural sensitivity to ensure successful public awareness, community engagement, and health education.

5. Challenges in preventing MVD epidemics in Africa

The healthcare infrastructure in many African countries faces significant limitations, particularly in remote and high-risk regions where MVD outbreaks are most likely to occur.^{74,76} Specific challenges include inadequate facilities for managing patients requiring isolation, limited

access to caves and mining areas where exposure typically occurs, difficulties in rapid diagnosis due to limited laboratory capacity, and insufficient training for healthcare workers on filovirus-specific protocols.⁶⁵ Many healthcare facilities lack essential resources, including isolation wards, personal protective equipment (PPE), and adequate medical supplies, which are critical for controlling viral hemorrhagic fevers like MVD.³⁷ Facilities are often understaffed, with healthcare workers who may not be specifically trained to handle infectious diseases of this nature.⁹² The lack of skilled personnel, particularly in rural areas, hinders the capacity for rapid response, accurate diagnosis, and effective patient care during an outbreak.⁸³ Additionally, the absence of specialized training programs for healthcare workers exacerbates the risk of in-hospital transmission, putting healthcare staff and patients at greater risk.⁷⁵ Healthcare settings require specific protocols for MVD that include enhanced biosafety measures, specialized PPE different from standard protocols, and training on the unique clinical presentation and management of filovirus infections.⁹³ These systemic weaknesses create significant barriers to preventing and containing MVD outbreaks, emphasizing the need for targeted investment in healthcare resources, training, and infrastructure.⁸⁵

5.1. Funding and Resource Allocation

Securing consistent funding for infectious disease preparedness remains a critical challenge in preventing MVD epidemics across Africa.^{74,76} Many African nations rely heavily on international aid to fund public health initiatives, including epidemic preparedness. However, international support can fluctuate based on global priorities and donor interests, leading to inconsistent funding streams.⁹⁴ This reliance on external funding makes it challenging for countries to maintain steady supplies of essential resources, such as laboratory equipment, PPE, and medications, or to invest in long-term healthcare infrastructure improvements.³⁷ Furthermore, resource allocation within national budgets is often limited as governments prioritize other pressing socioeconomic needs.⁷⁵ Without stable financial support, preventive and responsive measures for MVD outbreaks can be insufficient and untimely, increasing the risk of uncontrolled spread.⁸⁵ Sustainable, locally driven funding mechanisms are essential to reduce dependency on international aid and ensure that resources are consistently available for epidemic preparedness.⁹²

5.2. Cross-border coordination

Like other infectious diseases, Marburg virus does not recognize borders, making cross-border coordination critical for effective monitoring, reporting, and containment.^{37,64} However, African countries often struggle with establishing strong regional cooperation for disease surveillance and information-sharing, especially in areas where cross-border movement is frequent.⁹⁵ Although organizations such as the Africa Centres for Disease Control and Prevention (Africa CDC) have taken steps to strengthen regional cooperation, gaps still exist in standardized reporting systems and joint outbreak response strategies.⁹² Differing national policies, varying levels of health system readiness, and logistical challenges in coordinating across borders further complicate efforts to contain the virus.⁹⁶ When cases appear near border regions, delayed information-sharing and inconsistent containment protocols can allow the virus to spread to neighboring areas, complicating response efforts and increasing the risk of widespread transmission.^{75,97}

5.3. Cultural practices

Cultural beliefs and practices also present unique challenges in managing and preventing MVD outbreaks. In many African communities, traditional customs regarding healthcare-seeking behavior, burial practices, and perceptions of illness influence responses to infectious

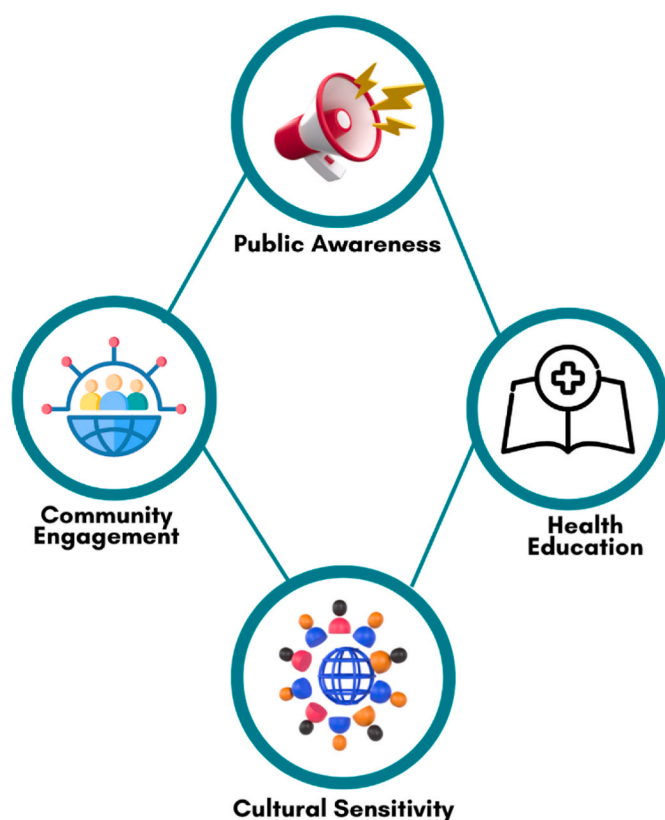


Fig. 1. Key Components of Community-Based Marburg Virus Prevention in Africa. This figure illustrates the interconnected elements crucial for effective Marburg virus prevention at the community level in Africa.

diseases.^{74,76}

For example, traditional burial practices, which often involve direct contact with the deceased, may increase the risk of MVD transmission, though specific evidence for such transmission requires further documentation.²⁶ Additionally, in some regions, there is a deep-rooted distrust of modern healthcare systems, leading individuals to avoid seeking medical care or following public health guidelines.³⁷ This distrust is sometimes fueled by previous experiences with healthcare interventions perceived as invasive or culturally insensitive.⁶¹ To address these barriers, public health authorities must engage communities in culturally appropriate ways, working with local leaders and using tailored messaging to encourage compliance with preventive measures and containment protocols.⁹⁸

5.4. Vaccine and treatment development

One of the most significant challenges in preventing MVD epidemics is the absence of licensed vaccines and specific treatments for the virus.^{99,100} Current antiviral drugs show limited efficacy against MARV, and supportive care remains the primary treatment approach. Several vaccine candidates are under development, including viral vector-based vaccines and mRNA platforms, but none have completed phase III trials or received regulatory approval for widespread use.^{101,102} This lack of preventive and therapeutic options leaves healthcare providers reliant on supportive care to manage symptoms, with no effective means of directly combating the virus or preventing its spread among at-risk populations.¹⁰³ The limited treatment options make it essential to focus on preventive measures. Yet, without a vaccine, the risk of rapid transmission remains high, especially in healthcare settings where frontline workers are highly exposed.¹⁰⁴ Recent advances in vaccine development include promising results from VSV-vectored vaccines and ChAd3-based platforms, but implementation in African settings faces challenges including cold chain requirements, regulatory approval processes, and community acceptance.^{86,105} The absence of vaccines and targeted treatments highlights the urgent need for accelerated research and development efforts, supported by sustained funding and international collaboration, to develop effective medical interventions for MVD control.¹⁰⁶ The complex interplay of challenges in preventing MVD epidemics in Africa is visualized in Fig. 2, highlighting the need for a multifaceted approach to address healthcare infrastructure, funding, cross-border coordination, and cultural practices simultaneously.

6. Concerns with epidemic preparedness and response

One of the primary concerns in Africa's epidemic preparedness for Marburg virus is the difficulty in mobilizing a rapid response, especially in rural and remote areas where outbreaks are more likely to emerge.^{37,76} These regions often have limited healthcare infrastructure, including inadequate transportation, few medical personnel, and a lack of specialized facilities for treating infectious diseases.⁷⁵ Mobilizing a response team quickly in such settings can be challenging, as resources must often be transported over long distances, further delaying interventions.⁷⁴ The time lost in mobilizing a response can allow the virus to spread undetected, heightening the risk of a larger outbreak.⁸³ For effective containment, it is crucial to establish well-trained, decentralized rapid response units that can operate independently and address outbreaks swiftly, even in challenging locations.¹⁰⁷

6.1. Supply chain disruptions

Access to essential supplies, such as personal protective equipment (PPE), medical devices, and pharmaceuticals, remains a significant concern in preventing and managing MVD outbreaks.^{37,76} Supply chains in many African countries are vulnerable to disruptions, whether due to logistical challenges, reliance on imported goods, or limited local production capacity.⁷⁵ During outbreaks, demand for PPE and other

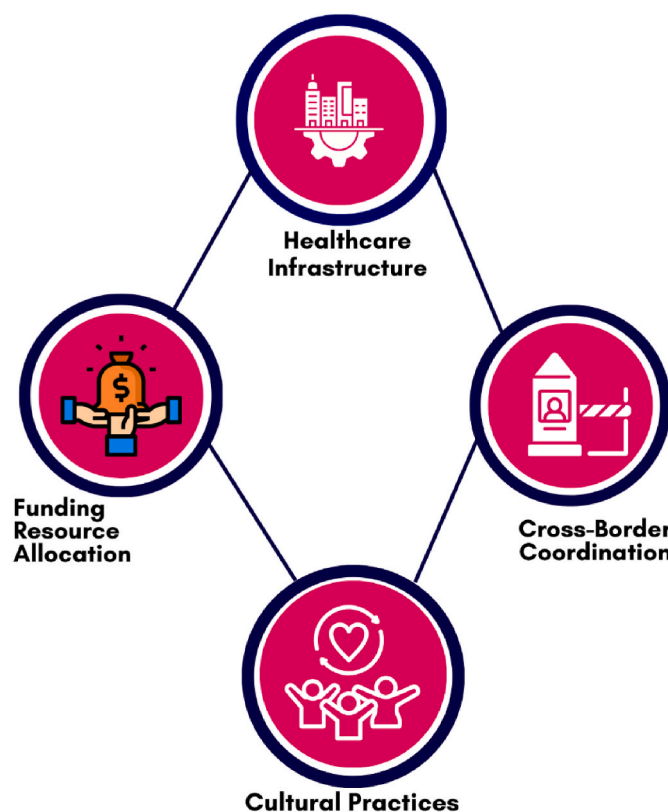


Fig. 2. Key Challenges in Preventing Marburg Virus Epidemics in Africa. This figure illustrates the four main challenges preventing Marburg virus epidemics in Africa. The diagram comprises four interconnected circles representing Healthcare Infrastructure, Funding and Resource Allocation, Cross-Border Coordination, and Cultural Practices.

medical supplies increases rapidly, often outstripping local capacity and causing shortages.⁸⁵ This was observed during previous Ebola outbreaks, where severe shortages of essential materials hindered containment efforts and put healthcare workers at higher risk.¹⁰⁸ Supply chain vulnerabilities also impact the availability of basic medical equipment needed for patient care and isolation.⁹² Building resilient, localized supply chains and stockpiling critical items are essential to mitigate these disruptions and ensure that healthcare facilities can respond effectively to emerging MVD cases.³⁸

6.2. Risk communication

Effective risk communication is crucial in managing public responses during MVD outbreaks, but African countries face notable challenges in relaying timely and accurate information to the public.^{76,98} Limited access to communication infrastructure, especially in rural areas, can hinder the dissemination of critical health messages.³⁷ In many cases, misinformation and rumors spread rapidly, causing panic or leading to mistrust in healthcare interventions.⁸⁸ Clear and culturally sensitive communication is necessary to ensure communities understand the risks associated with Marburg virus, the importance of adhering to containment measures, and the steps to protect public health.⁷⁴ Effective risk communication also involves building trust with communities, which can be challenging if there is a history of distrust in public health authorities.⁷⁵ Ensuring that accurate information reaches people promptly prevents fear-driven behavior and encourages cooperation with containment measures, such as isolation, quarantine, and adherence to hygiene protocols.⁸⁶

6.3. Political and economic constraints

Political and economic factors significantly impact the effectiveness of Africa's epidemic preparedness and response efforts. Political instability in some regions creates inconsistencies in policy implementation and makes it difficult to maintain public health programs and infrastructure.⁷⁴ In unstable political environments, there may be frequent leadership changes, leading to shifts in public health priorities and weakening continuity in outbreak preparedness.⁷⁷ Economic challenges further exacerbate these issues, as limited national budgets restrict the funding for health services, training programs, and essential infrastructure.⁷⁵ Countries with strained economies often prioritize immediate socio-economic needs, leaving limited resources for proactive epidemic preparedness.¹⁰⁹ Moreover, dependency on international aid for epidemic response introduces additional complications, as funding from international donors may be delayed or contingent on external factors.⁸³ Political will and economic stability are crucial for maintaining the consistent, proactive measures required to strengthen preparedness for MVD outbreaks, underscoring the importance of securing stable, long-term investments in public health infrastructure across the continent.⁶¹

7. Recommendations for strengthening Africa's preparedness

To enhance disease surveillance for Marburg virus, African nations should invest in building robust, localized surveillance networks that can identify and monitor potential outbreaks quickly. Deploying real-time disease surveillance systems, such as mobile-based reporting platforms, can improve data collection and communication between remote areas and central health authorities.³⁷ Regular training for community health workers to identify and report symptoms of hemorrhagic fevers can also help detect cases early.¹¹⁰ Expanding laboratory networks, particularly in high-risk areas, is crucial to support faster diagnostics and prevent delays caused by sample transportation.⁶⁷ Specific laboratory requirements for MARV include BSL-4 containment facilities, specialized diagnostic protocols, and trained personnel capable of handling high-risk pathogens safely.¹¹¹ Integrating MVD monitoring with existing infectious disease programs can further streamline data collection on virus prevalence and better prepare countries to respond effectively to emerging cases.¹¹²

7.1. Capacity building

Building healthcare capacity is essential to ensure that healthcare workers are prepared to manage MVD cases, especially in remote, high-risk regions.⁷⁶ Training programs should be developed to equip healthcare providers with MARV-specific protocols, including proper use of enhanced personal protective equipment (PPE), safe isolation practices specific to filoviruses, and infection prevention strategies tailored to rural and resource-limited settings.¹¹³ Establishing mobile health units with trained personnel can provide timely support to remote regions during outbreaks.¹¹⁴ Additionally, simulation exercises and preparedness drills should be conducted regularly to improve response time and preparedness among healthcare teams, ensuring they are familiar with procedures specific to managing hemorrhagic fevers.⁹² Training should specifically address the differences between MVD and other viral hemorrhagic fevers, including unique clinical presentations, required biosafety measures, and specialized laboratory protocols.¹¹⁵

7.2. Improving community awareness

Effective community awareness programs are critical for preventing MVD transmission, particularly in regions where the virus may emerge.^{76,77} These programs should use culturally sensitive approaches that respect local beliefs and practices while educating communities about MVD symptoms, transmission risks, and prevention strategies.⁷⁵

Education should specifically focus on human-bat contact reduction, including awareness about cave and mine safety, proper protective equipment for essential work in high-risk areas, and recognition of situations requiring immediate medical attention.¹¹⁶ Involving trusted local leaders, community health workers, and traditional healers can help increase public trust in health interventions.⁸⁸ Communication materials, including posters, radio broadcasts, and social media campaigns, should be tailored to the languages and cultural contexts of target communities to improve accessibility and engagement.⁷⁸ By building awareness and encouraging preventive behaviors, these programs can reduce stigma, promote early reporting of symptoms, and ensure community cooperation with containment measures during outbreaks.⁶¹

7.3. Advocacy for funding and research

Sustained financial support is essential for maintaining preparedness and advancing research on Marburg virus.^{99,100} Governments, alongside regional and international organizations, should advocate dedicated funding to build resilient health systems capable of handling MVD outbreaks.¹¹⁷ This funding is vital not only for resource procurement and healthcare training but also for accelerating vaccine and therapeutic research, including support for clinical trials in African settings.¹¹⁸ Although there are ongoing efforts to develop MVD vaccines, progress remains slow without significant investments.¹¹⁹ Recent developments include promising vaccine candidates such as VSV-MARV and ChAd3-MARV, but these require substantial investment for phase III trials and regulatory approval.^{86,105} Increasing collaboration with global health organizations, research institutions, and the private sector can attract more resources and expedite the development of vaccines and treatments.¹¹² Advocating for consistent funding sources and research investments will strengthen Africa's ability to respond effectively to MVD outbreaks and reduce dependency on emergency international aid.¹²⁰

7.4. Enhancing regional cooperation

Regional cooperation is crucial for monitoring and managing MVD outbreaks that may spread across borders.^{37,75} The African Union (AU), along with regional health bodies and international organizations, should work to establish standardized reporting systems and shared protocols for MVD preparedness.⁷⁶ Collaborative frameworks, such as the Africa CDC's Regional Integrated Surveillance and Laboratory Networks (RISLNET), can improve information sharing, support joint training initiatives, and coordinate cross-border response efforts specifically for filovirus outbreaks.⁶⁴ Holding regular inter-country workshops, drills, and strategic planning sessions can help ensure that neighboring countries are aligned in their outbreak response and can act collectively when cases are detected near borders.⁸⁷ Regional cooperation should include standardized protocols for cross-border case investigation, shared laboratory networks, and coordinated public health messaging to prevent misinformation spread.¹²¹ Strengthening these regional frameworks will enable countries to respond to MVD threats more effectively, leveraging shared resources and expertise to prevent large-scale epidemics.⁹⁵

8. Limitations of the review

This narrative review has several limitations that should be acknowledged. First, the review methodology was narrative rather than systematic, which may have resulted in selection bias and incomplete coverage of available literature. The search strategy, while comprehensive, may have missed relevant studies published in non-English languages or in regional journals with limited international visibility. Second, the quality and reliability of data from outbreak reports vary considerably, particularly from earlier outbreaks where surveillance and

reporting systems were less developed. Third, many of the included studies are descriptive reports rather than analytical studies, limiting the ability to draw causal inferences about preparedness factors and outbreak outcomes. Fourth, there is significant heterogeneity in healthcare systems, economic conditions, and preparedness levels across African countries, making broad generalizations challenging. Fifth, the rapidly evolving nature of MVD research and preparedness activities means that some recent developments may not be fully captured in the available literature. Finally, the review relies heavily on published literature and may not fully reflect unpublished experiences, local knowledge, or ongoing preparedness activities that have not been formally documented. Despite these limitations, this review provides valuable insights into the current state of MVD preparedness in Africa and identifies key areas for improvement.

9. Conclusion

This review highlights the pressing need for Africa to enhance its preparedness for MVD outbreaks, emphasizing several critical gaps in surveillance, healthcare infrastructure, community awareness, and regional coordination. Marburg virus poses a serious threat, with a mortality rate of 24-100%, limited licensed treatment options, and significant potential for human-to-human transmission, particularly in healthcare settings. Major challenges identified include inadequate healthcare infrastructure in remote high-risk areas, inconsistent funding for preparedness activities, cultural barriers to public health measures, and the absence of licensed vaccines and specific treatments. Key differences from Ebola virus disease response include the need for enhanced biosafety measures, specialized protocols for cave and mining exposure prevention, and unique laboratory diagnostic requirements. Past outbreaks in Uganda, Kenya, Angola, Ghana, Tanzania, and Rwanda have demonstrated the risks associated with insufficient health resources, delays in response, and cultural barriers to containment efforts. Key findings underscore the importance of strengthening surveillance systems to improve early detection, building healthcare capacity in remote areas, and increasing public awareness through culturally tailored programs.

Preventing MVD epidemics will require a multi-faceted approach that combines infrastructure investment, regional collaboration, community involvement, and human-bat contact reduction strategies. Essential response components include establishing BSL-4 laboratory networks, implementing MARV-specific training programs for healthcare workers, developing culturally sensitive community engagement strategies, and creating standardized cross-border surveillance protocols. Regional collaboration, supported by frameworks from organizations such as the African Union and Africa CDC, can enhance information sharing and cross-border coordination. Community involvement, achieved through culturally sensitive outreach and trust-building, is critical to ensure cooperation with public health measures. Accelerated research and development of vaccines and treatments, supported by sustained international funding and collaboration, remains a priority for long-term preparedness. The implementation of human-bat contacts reduction measures, particularly in mining and cave environments, represents a crucial prevention strategy that requires immediate attention. By addressing these areas collectively, African nations can strengthen their resilience against MVD outbreaks, minimizing the risk of widespread epidemics and safeguarding public health across the continent.

CRediT authorship contribution statement

David B. Olawade: Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Formal analysis, Conceptualization. **Navami Leena:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Sandra Chinaza Fidelis:** Writing – review & editing, Writing – original

draft, Software, Methodology, Conceptualization. **Olalekan John Okesanya:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Methodology. **Chibuikwe S. Alisi:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Eghosasere Egbon:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Augustus Osborne:** Conceptualization, Writing – review & editing.

Consent to publish

All authors consent for publication.

Ethics statement

Approval from the Ethics Committee was not required.

Data availability statement

Data sharing does not apply to this article, as no datasets were generated or analyzed during the current study.

Clinical trial number

Not applicable.

Consent to participate

Not applicable.

Funding

The authors did not receive any funding for this study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Rougeron V, Feldmann H, Grard G, Becker S, Leroy EM. Ebola and Marburg haemorrhagic fever. *J Clin Virol*. 2015;64:111–119.
2. Kuhn JH, Adkins S, Alioto D, et al. 2020 taxonomic update for phylum Negarnaviricota (Riboviria: Orthornavirae), including the large orders Bunyavirales and Mononegavirales. *Arch Virol*. 2020;165(12):3023–3072.
3. El-khamissy TR, Abdo MR. The problematic diseases of viral hemorrhagic fever: insights into ebola, marburg, and dengue fever viruses. *ERU Res J*. 2024.
4. Ristanović ES, Kokoškov NS, Crozier I, Kuhn JH, Gligić AS. A forgotten episode of Marburg virus disease: belgrade, Yugoslavia, 1967. *Microbiol Mol Biol Rev*. 2020;84(2), e00095-19.
5. Shanes E. Marburg virus disease. *Int J Nurs Educ Res*. 2022;10(4):403–405.
6. Mitu RA, Islam MR. The current pathogenicity and potential risk evaluation of marburg virus to cause mysterious "Disease X"—An update on recent evidences. *Environ Health Insights*. 2024;18, 11786302241235809.
7. Shenge JA, Opayele AV. The impact and control of emerging and re-emerging viral diseases in the environment: an African perspective. *Current Microbiological Research in Africa: Selected Applications for Sustainable Environmental Management*. 2020: 185–202.
8. Johnson ED, Johnson BK, Silverstein D, et al. Characterization of a new Marburg virus isolated from a 1987 fatal case in Kenya. *Arch Virol Suppl*. 1996;11:101–114.
9. Srivastava S, Sharma D, Kumar S, et al. Emergence of Marburg virus: a global perspective on fatal outbreaks and clinical challenges. *Front Microbiol*. 2023;14, 1239079.
10. Abir MH, Rahman T, Das A, et al. Pathogenicity and virulence of Marburg virus. *Virulence*. 2022 Apr 1;13(1):609–633.
11. Kinimi E. Marburg virus disease in Sub-Saharan Africa: a review of currently available comprehensive genomic data up to 2024. *Zoonotic Dis*. 2025 Mar 7;5(1): 6.
12. Muvunyi CM, Mohamed NS, Siddig EE, Ahmed A. Genomic evolution and phylodynamics of the species Orthomarburgvirus marburgense (Marburg and ravn

- viruses) to understand viral adaptation and Marburg virus disease's transmission dynamics. *Pathogens*. 2024;13(12):1107.
13. Letafati A, Ardekani OS, Karami H, Soleimani M. Ebola virus disease: a narrative review. *Microb Pathog*. 2023 Aug 1;181, 106213.
 14. Nabeshima T, Ngwe Tun MM, Thuy NT, et al, Nagasaki University Vietnam Research Group. An outbreak of a novel lineage of dengue virus 2 in Vietnam in 2022. *J Med Virol*. 2023 Nov;95(11), e29255.
 15. Karami H, Ghahdarijani FG, Abbasi A, Yaghoobizad S, Najafabadi AQ. Global outbreak of mpox (Clade ib): an emerging threat to public health in Iran. *Iran J Public Health*. 2025 Mar;54(3):672.
 16. Moreira HM, Sgorlon G, Queiroz JA, et al. Outbreak of Oropouche virus in frontier regions in western Amazon. *Microbiol Spectr*. 2024 Mar 5;12(3), e01629-23.
 17. Deshpande GR, Sapkal GN, Salunke A, et al. An outbreak of Zika virus in western India in the metropolis of Pune in the monsoon of 2024. *J Infect Public Health*. 2025 May 1;18, 102720.
 18. Karami H. HKU5-CoV lineage 2 (HKU5-CoV-2): a novel bat-infecting coronavirus with likely 'spillover' risk. *New Microbes New Infect*. 2025 Jun 23;66, 101611.
 19. Wood MR, de Vries JL, Epstein JH, Markotter W. Variations in small-scale movements of, Roussetus aegyptiacus, a Marburg virus reservoir across a seasonal gradient. *Front Zool*. 2023;20(1):23.
 20. Towner JS, Pourrut X, Albariño CG, et al. Marburg virus infection detected in a common African bat. *PLoS One*. 2007;2(8), e764.
 21. Towner JS, Amman BR, Sealy TK, et al. Isolation of genetically diverse Marburg viruses from Egyptian fruit bats. *PLoS Pathog*. 2009;5(7), e1000536.
 22. Letafati A, Fakhr SS, Najafabadi AQ, Karami N, Karami H. Marburg virus disease: a narrative review. *Health Sci Rep*. 2025 May;8(5), e70669.
 23. Uppala PK, Karaman SK, Kandra NV, Edhi S. Marburg virus disease: emerging threat, pathogenesis, and global public health strategies. *World J Virol*. 2025 Jun 25;14(2), 103576.
 24. Karami H, Letafati A, Fakhr SS. Can Marburg virus be sexually transmitted? *Health Sci Rep*. 2024 Aug;7(8), e2270.
 25. Ofori EK, Nyarko ENY. Current advances in Marburg virus disease. In: Amponsah SK, Shegokar R, Pathak YV, eds. *Rising Contagious Diseases: Basics, Management, and Treatments*. Wiley; 2024:129–144. <https://doi.org/10.1002/9781394188741.ch11>.
 26. Park C. Traditional funeral and burial rituals and Ebola outbreaks in West Africa: a narrative review of causes and strategy interventions. *J Health Soc Sci*. 2020;5(1): 73.
 27. Abir MH, Rahman T, Das A, et al. Pathogenicity and virulence of Marburg virus. *Virulence*. 2022;13(1):609–633.
 28. Goh E, Singh R. Viral hemorrhagic fever. In: *Infections and Pregnancy*. Singapore: Springer Singapore; 2022:137–150.
 29. Jacob ST, Crozier I, Fischer WA, et al. Ebola virus disease. *Nat Rev Dis Primers*. 2020;6(1):13.
 30. Ghazy RM, Gebreal A, El Demerdash BE, et al. Development and validation of a French questionnaire that assesses knowledge, attitude, and practices toward Marburg diseases in sub-saharan African countries. *Public Health*. 2024;230: 128–137.
 31. Cuomo-Dannenburg G, McCain K, McCabe R, et al. Marburg virus disease outbreaks, mathematical models, and disease parameters: a systematic review. *Lancet Infect Dis*. 2024;24(5):e307–e317.
 32. Conrad JL, Johnston J, Geldenhuys P, et al. Epidemiologic investigation of Marburg virus disease, Southern Africa, 1975. *Am J Trop Med Hyg*. 1978;27(6): 1210–1215.
 33. Bausch DG, Nichol ST, Muyembe-Tamfum JJ, et al. Marburg hemorrhagic fever associated with multiple genetic lineages of virus. *N Engl J Med*. 2006;355(9): 909–919.
 34. Ligon BL. Outbreak of Marburg hemorrhagic fever in Angola: a review of the history of the disease and its biological aspects. *Semin Pediatr Infect Dis*. 2005;16 (3):219–224.
 35. Adjemian J, Farnon EC, Tshioko F, et al. Outbreak of Marburg Hemorrhagic fever among miners in Kamwenge and Ibanda districts, Uganda, 2007. *J Infect Dis*. 2011; 204(Suppl 3):S796–S799.
 36. Bonney JK, Adu B, Sanders T, et al. Marburg virus disease in Ghana. *N Engl J Med*. 2023;388(25):2393–2394.
 37. Sibomana O, Kubwimana E. First-ever Marburg virus disease outbreak in Equatorial Guinea and Tanzania: an imminent crisis in West and East Africa. *Immun Inflamm Dis*. 2023;11(8), e980.
 38. Mmbaga V, Mrema G, Ngenzi D, et al. Epidemiological description of Marburg virus disease outbreak in Kagera region, Northwestern Tanzania. *PLoS One*. 2024; 19(8), e0309762.
 39. Grobusch MP, Jokelainen P, Wyllie AL, et al. Marburg virus disease outbreak in Rwanda, 2024. *Clin Microbiol Infect*. 2024;393:983–993. <https://doi.org/10.1016/j.cmi.2024.10.023>.
 40. Kilangisa L, Max B, Kayuni E, Shao E, Mashauri H. Marburg virus disease: lesson learned from the first outbreak encounter in Tanzania. *Int J Surg Glob Health*. 2023; 6(5), e186.
 41. Smith DH, Isaacson M, Johnson KM, et al. Marburg-virus disease in Kenya. *Lancet*. 1982;319(8276):816–820.
 42. Towner JS, Khristova ML, Sealy TK, et al. Marburgvirus genomics and association with a large hemorrhagic fever outbreak in Angola. *J Virol*. 2006;80(13): 6497–6516.
 43. Brauburger K, Hume AJ, Mühlberger E, Olejnik J. Forty-five years of Marburg virus research. *Viruses*. 2012;4(10):1878–1927.
 44. Nyakarahuka L, Schafer LJ, Balinandi S, et al. A retrospective cohort investigation of seroprevalence of Marburg virus and ebolaviruses in two different ecological zones in Uganda. *BMC Infect Dis*. 2020;20(1):575.
 45. Makenov MT, Boumbaly S, Tolno FR, et al. Marburg virus in Egyptian Roussetus bats in Guinea: investigation of Marburg virus outbreak origin in 2021. *PLoS Neglected Trop Dis*. 2023;17(4), e0011279.
 46. Rwanda Biomedical Centre. Marburg virus information. Available at: <https://rbc.gov.rw/marburg/>; 2024.
 47. Patel VA, Verma A, Verma M, et al. Marburg virus in Tanzania: a detailed outbreak review. *Clinical Infection in Practice*. 2025 Feb 11;25, 100414.
 48. Venkatesan P. Marburg virus outbreak in Tanzania. *Lancet Microbe*. 2025;6(5), 101121–1.
 49. Hewson R. Understanding viral haemorrhagic fevers: virus diversity, vector ecology, and public health strategies. *Pathogens*. 2024;13(10):909.
 50. Emperor DM, Mazzola LT, Wonderly Trainor B, Chua A, Kelly-Cirino C. Diagnostics for filovirus detection: impact of recent outbreaks on the diagnostic landscape. *BMJ Glob Health*. 2019 Feb;4(suppl 2), e001112.
 51. Nyakarahuka L, Kankya C, Krontveit R, et al. How severe and prevalent are Ebola and Marburg viruses? A systematic review and meta-analysis of the case fatality rates and seroprevalence. *BMC Infect Dis*. 2016;16(1).
 52. World Health Organization. Marburg virus disease. Available from: <https://www.who.int/news-room/fact-sheets/detail/marburg-virus-disease>; 2025.
 53. Petti S, Messano GA, Vingolo EM, Marsella LT, Scully C. The face of Ebola: changing frequency of haemorrhage in the West African compared with Eastern-Central African outbreaks. *BMC Infect Dis*. 2015;15(1).
 54. Boora S, Kaushik S, Yadav JP, Kaushik S, Kumar D. Marburg virus is nature's wake-up call: A bird's-eye view. *Med Microecol*. 2024;20, 100102. <https://doi.org/10.1016/j.medmic.2024.100102>.
 55. Chomel BB, Boulouis HJ, Chang CC, Setien AA, Stuckey MJ. Bat-related zoonoses. In: *Zoonoses: Infections Affecting Humans and Animals*. Cham: Springer International Publishing; 2023:1035–1070.
 56. Srivastava D, Kutikuppala L, Shanker P, et al. The neglected continuously emerging Marburg virus disease in Africa: a global public health threat. *Health Sci Rep*. 2023; 6(11), e1661.
 57. Oliaro P, Torreele E. Global challenges in preparedness and response to epidemic infectious diseases. *Mol Ther*. 2022;30(5):1801–1809.
 58. Alla D, Paruchuri SSH, Tiwari A, et al. The mortality, modes of infection, diagnostic tests, and treatments of Marburg virus disease: a systematic review. *Health Sci Rep*. 2023;6(9), e1545.
 59. Cross RW, Mire CE, Feldmann H, Geisbert TW. Post-exposure treatments for Ebola and Marburg virus infections. *Nat Rev Drug Discov*. 2018;17(6):413–434.
 60. Amman BR, Carroll SA, Reed ZD, et al. Seasonal pulses of Marburg virus circulation in juvenile Roussetus aegyptiacus bats coincide with periods of increased risk of human infection. *PLoS Pathog*. 2012;8(10), e1002877.
 61. Gulumbé BH, Uggh IH, Shehu A, Winchislaus E. Marburg virus in Tanzania: examining emergence, consequences, and mitigation approaches. *Health Low Resour Settings*. 2024;12(1), 11355.
 62. Mohanty A, Sharma S, Mehta R, et al. Rwanda's first Marburg virus outbreak. *J Trav Med*. 2024;31(8), taae139. <https://doi.org/10.1093/jtm/taae139>.
 63. Lamarque H. Key considerations: outbreak of Marburg virus disease in Rwanda, October 2024. *Social Science in Humanitarian Action Platform*. 2024.
 64. Ahmed I, Salsabil L, Hossain M, et al. The recent outbreaks of Marburg virus disease in African countries are indicating potential threat to the global public health: future prediction from historical data. *Health Sci Rep*. 2023;6(7), e1395.
 65. Kinyenje E, Hikororo J, Ngowi R, et al. Infection prevention and control of highly infectious pathogens in resource-limited countries: an experience from Marburg viral disease outbreak in Kagera Region-Tanzania. *BMC Infect Dis*. 2024;24(1):628.
 66. Emperor DM, Mbala-Kingebeni P, Ahuka-Mundeye S, et al. Ebola virus disease outbreaks in the Democratic Republic of the Congo: experience with 8 outbreaks (1976–2018). *J Infect Dis*. 2019;220(8):1285–1290.
 67. Shahzad M, Shaeen SK, Malikzai A. Marburg virus: africa's deadly intruder exposed. *Ann Med Surg*. 2023;85(10):5297–5298.
 68. Kugelmann JR, Keltbaum A, Jennings GB, et al. Evaluation of the potential impact of Ebola virus genomic drift on the efficacy of sequence-based candidate therapeutics. *mSphere*. 2021;6(1), e00227-20.
 69. Affara M, Lagu HI, Achol E, et al. The East African Community (EAC) mobile laboratory networks in Kenya, Burundi, Tanzania, Rwanda, Uganda, and South Sudan—From project implementation to outbreak response against Dengue, Ebola, COVID-19, and epidemic-prone diseases. *BMC Med*. 2021 Jul 9;19(1).
 70. Muvunyi CM, Claude J, Bigirimana N, et al. Evidence-based guidance for one health preparedness, prevention, and response strategies to marburg virus disease outbreaks. *Diseases*. 2024;12(12), 309.
 71. Agboh HNK, Adjei-Okai G, Adjei GA. Qualitative insights on emergency preparedness and response to marburg virus disease in Ghana: the role of risk communication and community engagement. *PLoS One*. 2024 Dec 12;19(12), e0309889.
 72. Reuben RC, Abunike SA. Marburg virus disease: the paradox of Nigeria's preparedness and priority effects in co-epidemics. *Bull Natl Res Cent*. 2023 Jan 27; 47(1).
 73. Gashugi Y, Byiringiro LB, Rukundo J, Izabayo J. From pandemic preparedness to epidemic control: leveraging COVID-19 lessons in Rwanda's fight against Marburg virus disease. *Ann Med Surg*. 2025 Jan 21;87(2):444–448.
 74. Okesanya O, Manirambona E, Olaleke N, et al. Rise of Marburg virus in Africa: a call for global preparedness. *Ann Med Surg*. 2023;85(10):5285–5290.

75. Oduoye M, Farhan K, Tariq M, Donatus D, Akilimali A. The looming threat of Marburg disease outbreak in Tanzania, East Africa – an editorial. *Ann Med Surg.* 2023;85(9):4194–4196.
76. Edward M, Scott G, John W, et al. Marburg virus outbreak in Tanzania: a threat to global health security. *Public Health Chall.* 2023;2(4), e140.
77. Aderinto N. A reflection on the Marburg virus outbreak in Tanzania: the importance of preparedness and prevention in public health – a correspondence. *Ann Med Surg.* 2023;85(6):2247–2249.
78. Shrivastava S, Shrivastava P. 2022 outbreak of Marburg virus disease in Ghana: public health alert. *Environ Dis.* 2022;7(3):80–82.
79. Naem A, Tabassum S, Zaidi S, et al. Deadly Marburg virus in Ghana, 2022 amidst monkeypox and COVID-19 pandemic: a distressing concern for public health. *Int J Surg.* 2023;109(3):571–573.
80. Geisbert TW, Jahrling PB. Exotic emerging viral diseases: progress and challenges. *Nat Med.* 2004;10(12 Suppl):S110–S121.
81. Owusu I, Adu C, Aboagye R, et al. Preparing for future outbreaks in Ghana: an overview of current COVID-19, monkeypox, and Marburg disease outbreaks. *Health Promot Perspect.* 2023;13(3):202–211.
82. Sah R, Reda A, Lashin B, et al. Marburg virus and monkeypox virus: the concurrent outbreaks in Ghana and the lesson learned from the Marburg virus containment. *J Pure Appl Microbiol.* 2022;16(SPL1):10.
83. Lukman L, Tawakalitu A, Patrick A, et al. Concurrent emergence of Marburg virus disease in Tanzania and Equatorial Guinea: a ticking time bomb. *Int J Surg Glob Health.* 2023;6(4), e233.
84. Kumar A, Gangwar R, Zargar A, et al. An outbreak of Marburg virus disease: World Health Organization. *Pharmaspire.* 2023;15(1):28–32.
85. Ezie K, Takoutsing B, Modeste D, et al. Marburg virus outbreak in Equatorial Guinea: need for speed. *Ann Glob Health.* 2024;90(1):28.
86. Cross RW, Longini IM, Becker S, et al. An introduction to the Marburg virus vaccine consortium, MARVAC. *PLoS Pathog.* 2022;18(11), e1010805.
87. Giri B, Malla A. The outbreak of marburg virus in Tanzania: an emerging global health threat. *Int J Multidiscip Res.* 2023;5(4):5990.
88. Wirsy F, Nkfusai C, Bain L. The SPIN framework to control and prevent the Marburg virus disease outbreak in Equatorial Guinea. *Pan Afr Med J.* 2023;44:110.
89. Sarki AM, Ezech A, Stranges S. Uganda as a role model for pandemic containment in Africa. *Am J Publ Health.* 2020 Dec;110(12):1800–1802.
90. Sprecher AG, Caluwaerts A, Draper M, et al. Personal protective equipment for filovirus epidemics: a call for better evidence. *JID (J Infect Dis).* 2015 Mar 27;212 (suppl 2):S98–S100.
91. Mnkeni E, Sindato C, Haonga T, et al. Role of Community Health Workers in early detection, reporting and response to infectious disease outbreaks: experience from Marburg Outbreak Management in Kagera region, Northwestern Tanzania. *Tanzan J Health Res.* 2024;25(4):1466–1471 [cited 2025 Dec 17].
92. Scarpa F, Bazzani L, Giovanetti M, et al. Update on the phylodynamic and genetic variability of Marburg virus. *Viruses.* 2023;15(8):1721.
93. Manning JT, Forrester JV, Paessler S. Lassa virus isolates from Mali and the Ivory Coast represent an emerging fifth lineage. *Front Microbiol.* 2015;6:1037.
94. Robinson J, Banerjee I, Leclézio A. Marburgvirus: a Global Virus, not just an African problem. *J Adv Intern Med.* 2023;12(1):82.
95. Guo Z, Zhao S, Sun S, et al. Estimating the serial interval of Marburg virus human-to-human transmission from a case cluster seeded by a cross-border traveler. *J Trav Med.* 2023. <https://doi.org/10.1093/jtm/taad100>.
96. Arale A, Lutukai M, Mohamed S, Bologna L, Stamidis K. Preventing importation of poliovirus in The Horn of Africa: the success of the cross-border health initiative in Kenya and Somalia. *Am J Trop Med Hyg.* 2019;101(1):100–106.
97. Ssendagire S, Tuhebwe D, Babirye S, et al. Mandated actions, legitimate role-bearers and expected actor networks in the management of infectious disease epidemics: the case of Marburg virus disease in Uganda. *Research Square.* 2020. <https://doi.org/10.21203/rs.3.rs-22886/v1>.
98. Roy S, Iturburu A, Mukherjee D, et al. Marburg virus disease outbreak amid COVID-19 pandemic: an emerging concern in Ghana, West Africa. *Int J Surg.* 2023; 109(3):597–598.
99. Dydyk M, Nowak A. Experimental success in Marburg virus vaccination. *Qual Sport.* 2024;22, 54483.
100. Rubin R. HHS funds development of vaccine against Marburg virus. *JAMA.* 2019; 321(16):1557.
101. Choudhary S, Malik YS, Tomar S. Identification of SARS-CoV-2 cell entry inhibitors by drug repurposing using in silico structure-based virtual screening approach. *Front Immunol.* 2020;11:1664.
102. Keshavarz M, Solaymani-Mohammadi F, Namdari H, et al. Metabolic host responses and therapeutic countermeasures against viral infections: the case of SARS-CoV-2 and influenza virus. *Arch Virol.* 2020;165(8):1719–1729.
103. Zhu W, Liu G, Cao W, et al. A cloned recombinant vesicular stomatitis virus-vectored marburg vaccine, PHV01, protects Guinea pigs from lethal marburg virus disease. *Vaccines.* 2022;10(7):1004.
104. Marzi A, Menicucci A, Engelmann F, et al. Protection against Marburg virus using a recombinant VSV-Vaccine depends on T and B cell activation. *Front Immunol.* 2018; 9:3071.
105. Hunegnaw R, Honko A, Wang L, et al. Rapid and durable protection against Marburg virus with a single-shot ChAd3-MARV GP vaccine. *bioRxiv.* 2021. <https://doi.org/10.1101/2021.12.22.472410>.
106. Albaqami F, Altharawi A, Altharwi H, et al. Computational modeling and evaluation of potential mRNA and peptide-based vaccine against Marburg Virus (MARV) to provide immune protection against Hemorrhagic fever. *BioMed Res Int.* 2023;2023, 5560605.
107. Nyakarahuka L, Shoemaker T, Balinandi S, et al. Marburg virus disease outbreak in Kween District Uganda, 2017: epidemiological and laboratory findings. *PLoS Neglected Trop Dis.* 2019;13(3), e0007257.
108. Englert EG, Kiwanuka R, Neubauer L. "When I die, let me be the last." community health worker perspectives on past Ebola and Marburg outbreaks in Uganda. *Glob Public Health.* 2018;14(8):1182–1192.
109. Keita M, Talisuna A, Chamla D, et al. Investing in preparedness for rapid detection and control of epidemics: analysis of health system reforms and their effect on 2021 Ebola virus disease epidemic response in Guinea. *BMJ Glob Health.* 2023;8(3), e010984.
110. Chakraborty S, Chandran D, Mohapatra R, et al. Marburg virus disease – a mini-review. *J Exp Biol Agric Sci.* 2022;10(4):689–696.
111. Feldmann H, Geisbert TW. Ebola haemorrhagic fever. *Lancet.* 2011;377(9768): 849–862.
112. Islam M, Akash S, Rahman M, Sharma R. Epidemiology, pathophysiology, transmission, genomic structure, treatment, and future perspectives of the novel Marburg virus outbreak. *Int J Surg.* 2023;109(1):36–38.
113. Oji M, Haile M, Baller A, et al. Implementing infection prevention and control capacity building strategies within the context of Ebola outbreak in a "Hard-to-Reach" area of Liberia. *Pan Afr Med J.* 2018;31:107.
114. Mahase E. Guinea reports West Africa's first ever case of Marburg virus disease. *Br Med J.* 2021;374, n1988.
115. Geisbert TW, Bausch DG, Feldmann H. Prospects for immunisation against Marburg and Ebola viruses. *Rev Med Virol.* 2010;20(6):344–357.
116. Amman BR, Nyakarahuka L, McElroy AK, et al. Marburgvirus resurgence in Kitaka mine bat population after extermination attempts, Uganda. *Emerg Infect Dis.* 2014; 20(10):1761–1764.
117. Manohar M, Lee V, Odunukwe E, et al. Advancements in marburg (MARV) virus vaccine research with its recent reemergence in Equatorial Guinea and Tanzania: a scoping review. *Cureus.* 2023;15(8), e42014.
118. Cross RW, Mire CE, Borisevich V, et al. The domestic ferret (*Mustela putorius furo*) as a lethal infection model for 3 species of ebolavirus. *J Infect Dis.* 2016;214(4): 565–569.
119. Comer JE, Escaffre O, Neef N, et al. Filovirus virulence in interferon α/β and γ double knockout mice, and treatment with favipiravir. *Viruses.* 2019;11(2):137.
120. Parish L, Stavale E, Houchens C, Wolfe D. Developing vaccines to improve preparedness for filovirus outbreaks: the perspective of the USA biomedical advanced research and development authority (BARDA). *Vaccines.* 2023;11(6): 1120.
121. Africa CDC. Marburg virus disease outbreak in Rwanda. Available at: <https://africa.cdc.org/news-item/marburg-virus-disease-outbreak-in-rwanda/>; 2024.