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REVIEW

Strategies for Managing Marburg Virus Disease Outbreaks: Lessons from the Rwanda Outbreak

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Abstract: Marburg Virus Disease (MVD) is a highly lethal viral hemorrhagic fever caused by the Marburg virus, a member of the filovirus family closely related to Ebola. Characterized by sudden onset of fever, hemorrhage, and multi-organ failure, MVD outbreaks pose significant public health challenges due to high mortality rates and limited medical countermeasures. The 2024 outbreak in Rwanda marked a critical point, with 66 confirmed cases and 15 fatalities, highlighting the urgent need for effective management strategies. This narrative review, reviews key lessons from Rwanda's response, emphasizing the critical importance of early detection through strengthened surveillance systems and rapid diagnostics, implementation of strict infection control practices, and robust community engagement to foster trust and cooperation. Rwanda's integrated approach, including supportive clinical care, innovative use of therapeutics, and swift deployment of investigational vaccines, illustrates effective outbreak containment. The study underscores the necessity of resilient health infrastructure, ongoing research, and Cross-border collaborations in mitigating future threats. Insights from Rwanda's recent experience provide valuable guidance for global preparedness and response strategies to contain and manage future Marburg outbreaks effectively.

Keywords: Marburg virus disease, outbreak management, infection control, early detection, Rwanda, community engagement, surveillance, therapeutics, vaccines

Introduction

Marburg Virus Disease (MVD) remains a formidable public health threat due to its high case fatality rates, complex clinical spectrum, and the absence of established medical countermeasures, such as approved vaccines or therapeutics.[1,2] First identified in 1967 during simultaneous outbreaks in Germany and Yugoslavia, MVD has since predominantly affected sub-Saharan Africa, with notable outbreaks in Angola, the Democratic Republic of Congo, Uganda, Ghana, Equatorial Guinea, and Tanzania.[3,4] These outbreaks have demonstrated the virus's capacity for rapid geographic spread, including instances linked to international travel and exposure to endemic wildlife reservoirs, primarily the Egyptian fruit bat (*Rousettus aegyptiacus*). Case fatality rates have varied widely—from 24% to nearly 100%—reflecting differences in healthcare infrastructure, outbreak response, and clinical management.[3,5]

Accurate and early diagnosis is essential for controlling MVD outbreaks, yet is inherently challenging because its initial symptoms—fever, headache, fatigue—overlap with common endemic illnesses such as sepsis, malaria and typhoid fever.[6] As the disease advances, symptoms can escalate to hemorrhage, jaundice, and multi-organ failure, but variability in presentations hampers timely identification. This clinical heterogeneity underscores the necessity for refined, evidence-based case definitions that encompass the full spectrum of disease manifestations, a lesson emphasized by Rwanda's recent outbreak in September 2024, which exhibited both classic hemorrhagic signs and cases with minimal symptoms resulted in 66 confirmed cases and 15 fatalities.[6]

Transmission dynamics further complicate control efforts. The primary mode involves direct contact with bodily fluids—such as blood, vomit, urine, and feces—from infected individuals.[7,8] The natural reservoir, the Egyptian fruit bat,

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often leads to outbreaks linked to exposure in caves or mines inhabited by these animals.[9] Human-to-human transmission is predominantly through contact with contaminated fluids during caregiving, inadequate infection control in healthcare settings, and traditional funeral practices involving the handling of deceased bodies.[9] Sexual transmission, with viral persistence in semen up to seven weeks post-recovery, necessitates targeted behavioral interventions for survivors.[10] Although airborne spread has not been documented in natural conditions, laboratory-based aerosol transmission has raised concerns, underscoring the importance of strict infection prevention protocols.[8]

The diagnostic landscape for MVD faces multiple hurdles—limited laboratory infrastructure, biosafety concerns, and cross-reactivity in serological tests such as ELISA.[11,12] Molecular methods like RT-PCR are invaluable in early detection but require sophisticated equipment often unavailable in resource-limited settings.[12] Moreover, early symptoms often mimic endemic diseases, delaying suspicion and confirmation. The lack of rapid, point-of-care diagnostic tools compounds these challenges, delaying effective isolation and containment measures—an issue vividly illustrated by the recent Rwanda outbreak, where swift diagnosis and prompt response were pivotal. In terms of management, current strategies rely predominantly on supportive care—fluid management, symptom alleviation, and addressing complications—but lack specific antiviral treatments or universally approved vaccines.[13–15] Experimental therapeutics and vaccine candidates have shown promise in preclinical and early clinical trials but remain unavailable for widespread use.[14] Consequently, outbreak control hinges on early detection, strict infection control practices, community engagement, and surveillance—lessons reinforced by Rwanda's experience, which highlighted the importance of coordinated response strategies in navigating the complexities of MVD outbreaks (Figure 1).

This narrative review aims to elucidate the lessons learned from Rwanda's recent outbreak and explore effective strategies for managing future Marburg virus disease outbreaks. Emphasis is placed on strengthening diagnostic capabilities, enhancing infection control measures, community engagement, and implementing targeted surveillance to mitigate the impact of this deadly disease. Understanding and operationalizing these lessons are critical steps toward navigating the challenges of MVD and safeguarding public health.

Early Detection and Outbreak Surveillance

The effective management of MVD outbreaks relies heavily on robust early detection and surveillance systems, particularly in Rwanda's context, which is characterized by various ecological zones and significant cross-border movement.[14] In collaboration

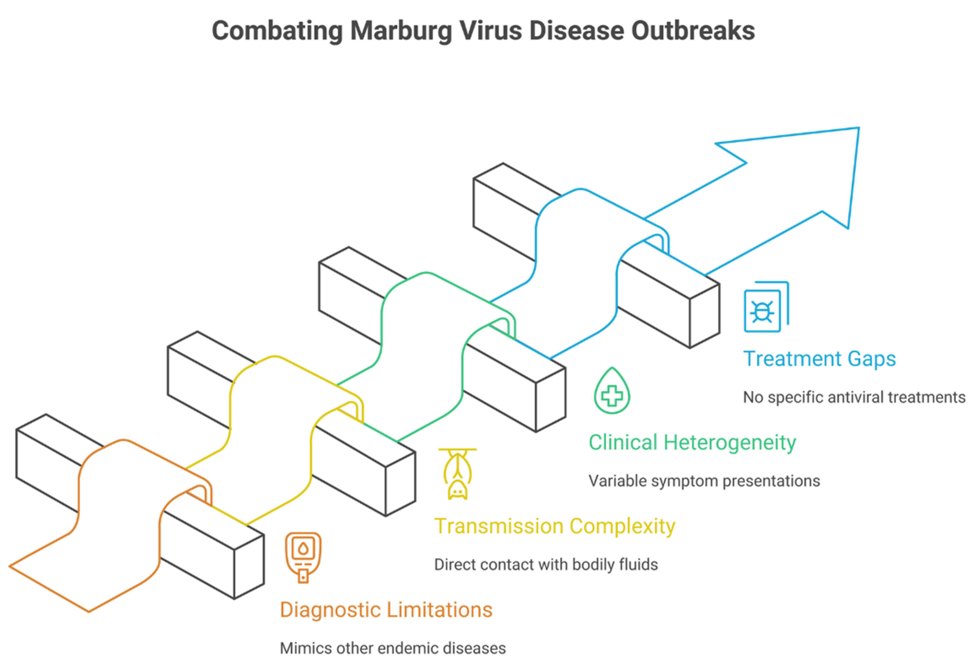

Figure 1 Illustrates the challenges faced by countries in combating outbreaks of the Marbury virus disease.

with the Rwanda Ministry of Health, the Rwanda Biomedical Center initiated a community-based, house-to-house campaign aimed at identifying symptoms of MVD.[14] This effort resulted in the screening of approximately 9,483,570 individuals across all five provinces, including the City of Kigali, representing an impressive 72% of the nation's total population. Analysis of the screening activities indicates that the northeastern region exhibited strong engagement in these efforts, with over 100,000 individuals screened.[14] This level of participation suggests effective local mobilization and resource allocation. However, the screening coverage was not uniformly distributed across the country. Areas in the southern and southwestern provinces reported significantly lower screening figures, which some may attribute to logistical hurdles and insufficient community involvement.[14] Geographic factors, such as the challenging mountainous terrain, may have further hampered accessibility and contributed to the uneven screening rates. Moreover, disparities in community health worker density and resource distribution across provinces are critical factors that may influence these differences in screening intensity. These variations underscore the imperative need to strengthen surveillance systems in areas lagging in screening, focusing on reallocating resources to ensure comprehensive monitoring and identification of MVD cases.

Strengthening Rwanda's surveillance systems involves enhancing existing healthcare infrastructure and fostering community engagement to ensure swift recognition of the disease. Sentinel surveillance was expanded in key healthcare facilities, especially district and provincial hospitals, with staff trained to identify early signs and symptoms such as sudden high fever, severe headache, malaise, myalgia, vomiting, diarrhea, and hemorrhagic manifestations like bleeding gums or blood in vomit or stool.[6] Given the nonspecific initial symptoms, training clinicians to distinguish MVD from other endemic febrile illnesses like malaria, typhoid, sepsis or dengue is essential, along with emphasizing detailed travel histories and potential contact with wildlife or previous cases[15] To achieve accurate differential diagnosis, the Rwanda Ministry of Health, in collaboration with the Rwanda Biomedical Center, developed a suspect case definition after consulting with experts from the World Health Organization (WHO) and the US Centers for Disease Control and Prevention (CDC).[6] This definition adapts the WHO's standard case criteria to the local context while preserving essential surveillance elements. The Marburg testing algorithm is based on clinical features, including fever, headache, muscle and joint pain, abdominal pain, vomiting, diarrhea, and abnormal bleeding, in conjunction with the patient's contact history.[6] A suspected case is tested for MVD if it presents with a history of contact and at least one symptom. Conversely, if a patient has no history of contact but develops at least three symptoms, they will also be tested for MVD. In instances where MVD results are negative, the patient will then be tested for other febrile illnesses, including malaria, typhoid fever, sepsis, and other viral hemorrhagic fevers such as dengue virus and Rift Valley fever, among others[6] (Figure 2).

Additionally, community-based surveillance reinforced through engagement with Community Health Workers (CHWs), who served as frontline identifiers in rural and remote regions. These workers underwent targeted training to recognize early symptoms, understand referral pathways, and educate communities on the importance of timely healthcare seeking.[16]

On the laboratory front, expanding diagnostic capacity is critical for early confirmation of cases. Rwandan authorities prioritize deploying portable and mobile laboratory units equipped for rapid PCR testing in high-risk regions, along with strengthening the capabilities of the Rwanda Biomedical Center (RBC) Central Public Health Laboratory for confirmatory testing.[12,17,18] Training laboratory personnel in biosafety procedures, sample collection, and safe transportation is vital to prevent laboratory-acquired infections.[12] While real-time PCR remains the gold standard for detecting Marburg virus, developing and deploying validated rapid diagnostic tests (RDTs) for preliminary screening can facilitate prompt triaging, especially in remote clinics.[12] Ensuring a reliable cold chain and a secure logistics network for transporting samples swiftly and maintaining accurate data management systems are crucial components for an effective laboratory response.

Contact tracing and active monitoring constitute another critical pillar of early detection. Rwanda's health response system established a meticulous contact tracing framework, prioritizing individuals who had close physical contact, shared living spaces, or were exposed to bodily fluids of confirmed or suspected cases. Collecting detailed data—including geolocation and exposure type—on contacts allows for better risk assessment and targeted follow-up.[15] Active monitoring of these contacts continue for at least 21 days—the known incubation period of the virus—through daily temperature checks and symptom screenings. Utilizing mobile health technologies such as SMS alerts or dedicated tracking apps enhanced real-time data collection and communication, enabling swift action when symptoms develop.[15] High-risk contacts exhibiting symptoms should be swiftly isolated and tested, with asymptomatic individuals monitored

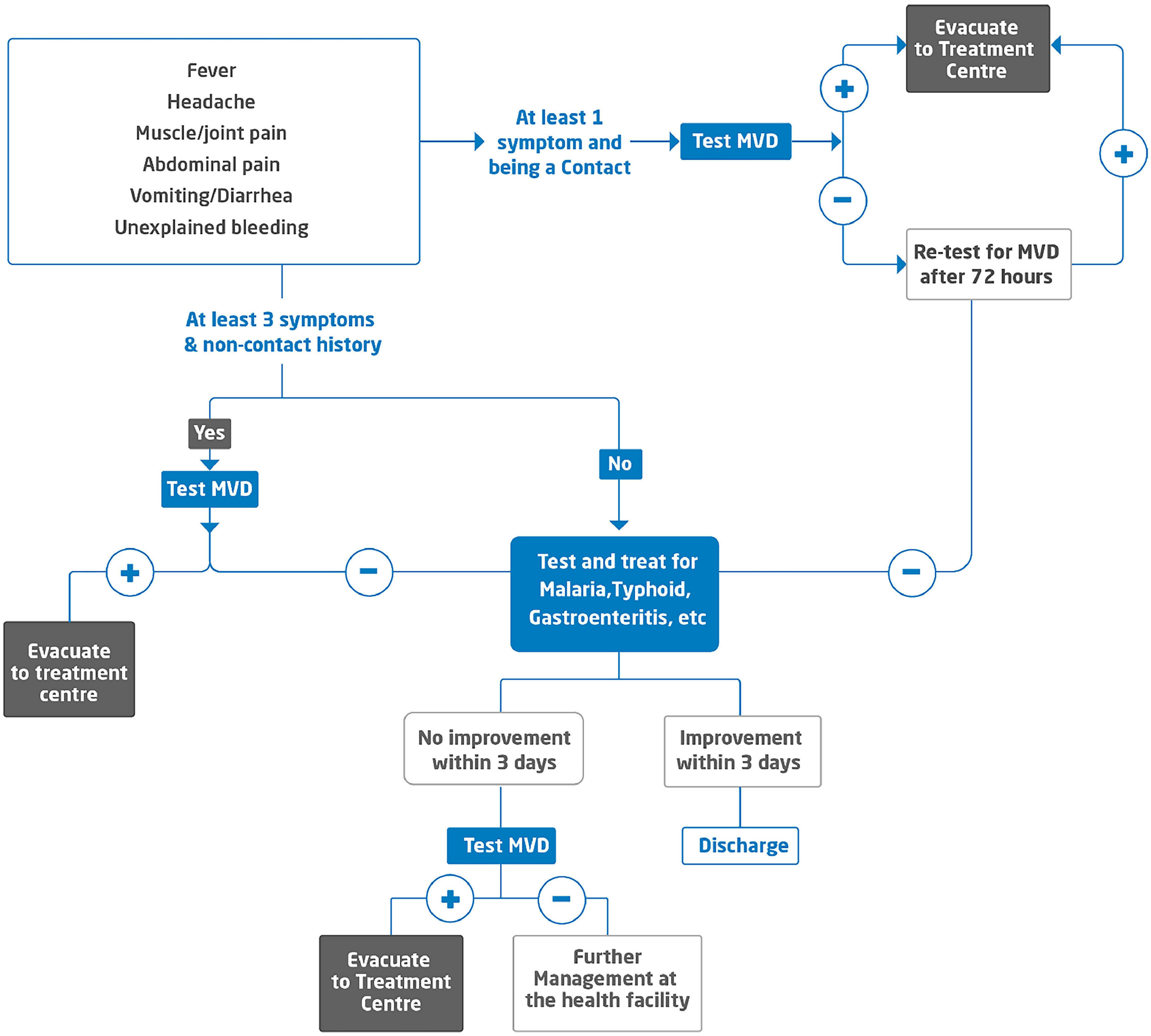

Figure 2 Illustrates the Marburg testing algorithm in Rwanda (adopted from Nsekuye et al, 2025).[6]

through quarantine measures, ideally in designated facilities, or through home quarantine supervised by community health personnel. Given Rwanda's cultural context, involving local leaders and traditional health practitioners in surveillance and contact tracing efforts can foster community trust, reduce stigma, and promote cooperation, all of which are essential for an effective outbreak response. In addition to these internal measures, establishing cross-border surveillance and coordination with neighboring countries such as Uganda and the Democratic Republic of Congo were done. Joint task forces, information-sharing platforms, and coordinated response plans can significantly improve Rwanda's capacity to detect and contain transboundary cases early.

Case Management and Clinical Care

Rwanda's approach to case management and clinical care during the Marburg virus outbreak underscored the critical importance of supportive treatment, as no specific antiviral therapies are currently approved for MVD.[4,15,17] Management primarily involved ensuring adequate hydration, relieving symptoms, and treating secondary infections to improve patient outcomes. To prevent the spread of infection within healthcare settings, Rwanda established dedicated isolation units equipped with strict infection control protocols, recognizing that these measures are vital in reducing nosocomial transmission. Notably, a UV-C light-emitting robot, capable of sterilizing 16 m^2 per minute, was deployed for disinfection in various areas, including hospital wards, intensive care units, laboratories, and on medical equipment.[19]

Healthcare workers were trained to adhere rigorously to PPE protocols—including gloves, gowns, masks, and eye protection—to minimize the risk of self-contamination. Proper handling and disposal of infected waste were prioritized, employing appropriate disinfectants and incineration when feasible, to mitigate environmental contamination. Regular environmental sanitation through disinfection of surfaces and medical equipment further reduced the persistence of the virus in healthcare environments, ensuring safer conditions for patients and staff. Recognizing that community practices can significantly influence transmission dynamics, Rwanda also addressed traditional burial customs involving direct contact with the deceased, implementing safe burial protocols conducted by trained personnel to decrease the risk of community spread.[6,20,21] These integrated strategies highlight that stringent hospital infection control measures, combined with community engagement and safe practices, are essential components in controlling disease spread and protecting both healthcare workers and the broader community during a filovirus outbreak.

Vaccination and Therapeutics

Rwanda's response to the Marburg virus outbreak offered valuable insights into effective outbreak management and highlighted the importance of a comprehensive and timely approach. Central to their strategy was the provision of advanced supportive care, including organ-support therapies such as dialysis and vasopressor treatments, which proved to be safe when rigorous infection prevention measures were in place.[15] These interventions significantly contributed to patient survival and underscored the necessity of strengthening healthcare capacities to manage severe cases during outbreaks.[15] The response also incorporated the judicious use of investigational therapeutics; for instance, patients treated with remdesivir exhibited a markedly lower mortality rate—only about 6%—compared to those who did not receive it, with mortality reaching nearly 86%.[15] Similarly, MBP091 appeared to offer some benefit, though definitive conclusions require further studies. While these treatments were not administered in randomized trials, their inclusion demonstrated that carefully monitored experimental therapies could be life-saving in emergency situations.[15] An especially notable lesson from the response was the rapid deployment of the ChAd3-MARV vaccine within 13 days of outbreak declaration, primarily targeting frontline healthcare workers under an adapted WHO protocol. Although the vaccine's impact on transmission was not directly measured, this swift action proved that investigational vaccines can be effectively integrated into outbreak responses without delaying essential intervention measures. Overall, Rwanda's experience highlighted that early activation of response efforts, combination of supportive care with experimental treatments, rapid vaccination deployment, and strict infection control are crucial components in controlling such deadly outbreaks. These lessons emphasize the need for preparedness, flexible strategies, and robust collaboration between governments, international agencies, and communities to protect populations and minimize mortality during future outbreaks.

Public Health and Community Engagement

From September 27 to December 2024, Rwanda faced its inaugural outbreak of MVD, presenting a significant public health challenge.[16] The outbreak severely impacted healthcare workers, underscoring critical deficiencies in infection prevention and control protocols within healthcare facilities.[16] The response from the Rwanda Ministry of Health and the Rwanda Biomedical Center exemplified rapid coordination and decisive action, significantly bolstered by the prompt assistance of both local and international partners. Collaborative efforts involving the World Health Organization (WHO), European Union Humanitarian Aid (ECHO), the UK's Foreign, Commonwealth and Development Office (FCDO), Africa Center for disease control and prevention Africa (CDC) and other development allies played a vital role in supporting the Rwandan government's initiatives.[16] This partnership facilitated the swift mobilization and deployment of expert teams, the procurement and distribution of essential supplies, and expedited capacity-building efforts for frontline healthcare workers and other professionals, all accomplished within days of confirming the outbreak.

The WHO's involvement was integral; the organization provided immediate technical and operational support, including crucial personal protective equipment (PPE), laboratory testing kits, tools for effective case management, and logistical assistance. Additionally, WHO collaborated closely with national authorities to enhance outbreak coordination, fortify surveillance systems, and develop impactful risk communication strategies. This multifaceted approach not only addressed the immediate needs of the outbreak response but also set a foundation for strengthening public health systems in Rwanda to better manage future health crises.

Additionally, under the oversight of health facilities and the MVD National Command Post, community health workers (CHWs) conducted house-to-house active case searches across all four provinces and Kigali City.[16] Individuals were screened for MVD symptoms based on the national case definition, with suspected cases promptly referred for laboratory testing. This proactive engagement with the community played a crucial role in early detection and containment of the outbreak.

Research and Preparedness

In Rwanda's response to Marburg Virus Disease, research and preparedness play a crucial role in strengthening outbreak control and prevention strategies.[6] The country has prioritized ongoing research to better understand the ecology of the virus, transmission pathways, and immune responses within local populations. This includes studies on environmental factors and wildlife reservoirs, which are vital for developing targeted prevention efforts. Rwanda's commitment to research informs the design of more effective vaccines, diagnostics, and therapeutics, enhancing early detection and treatment capabilities. Simultaneously, Rwanda has invested heavily in preparedness activities. The government has developed comprehensive contingency plans that clearly define roles for healthcare facilities, public health authorities, and international partners. Regular simulation exercises are conducted to test and improve response coordination, ensuring rapid mobilization during outbreaks. The country has also prioritized the stockpiling of essential supplies, such as PPE, diagnostic kits, and potential therapeutics, to guarantee readiness at all times. Strengthening healthcare infrastructure, especially in vulnerable and remote regions, has improved local capacity to manage cases effectively. Rwanda actively collaborates with international organizations to share knowledge, resources, and technical expertise, further bolstering its readiness. These integrated efforts in research and preparedness have positioned Rwanda to respond swiftly and effectively to Marburg Virus Disease outbreaks, minimizing their impact on communities and health systems alike.

Conclusion

The recent MVD outbreak in Rwanda provides pivotal lessons that are uniquely relevant for enhancing outbreak management strategies on both local and global scales. Key insights include the necessity of redefining case definitions and developing contextual diagnostic algorithms that capture the diverse clinical presentations of MVD. This outbreak underscores the urgency for policymakers to establish standard operating procedures specifically for protecting healthcare workers, thereby ensuring their safety and maintaining healthcare delivery during crises. Additionally, Rwanda's integrated response highlights the importance of community engagement and cross-sectoral collaboration as critical components of effective outbreak management. By involving local leaders and public health entities, the response fostered trust and ensured adherence to health measures, ultimately enhancing the overall effectiveness of containment strategies.

Rwanda's experience with MVD also illustrates the need for strengthened research capacity, particularly in understanding the epidemiology of MVD and its transmission dynamics. This can guide the development of targeted prevention efforts and inform vaccine research initiatives. Moreover, regional collaboration plays a significant role in fortifying health security, as cross-border efforts in surveillance and response amplify overall preparedness for future outbreaks. As we move forward, leveraging Rwanda's recent experiences will be instrumental in shaping robust public health policies, fostering innovation in vaccine and therapeutic development, and enhancing global health security measures. The lessons gleaned from this outbreak act as a blueprint for other nations grappling with similar infectious diseases, emphasizing that comprehensive, community-centric, and research-driven approaches are essential for mitigating the impacts of Marburg Virus Disease and other emergent threats.

Disclosure

The authors report no conflicts of interest in this work.

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