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Review Article

Ebola Virus Disease Risk Assessment in the Indian Population: Epidemiology, Risk Factors, and Preparedness for Disease Surveillance and Public Health Response

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A B S T R A C T

Despite remaining largely confined to the African continent, Ebola virus disease (EVD) continues to pose a serious global public health concern. India has yet to record a confirmed case, but the possibility of importation and the chain of transmission could trigger demands for cautious, evidence-based scrutiny and preparedness.

This review synthesizes findings from peer-reviewed literature, WHO surveillance data, and international epidemiological research to examine EVD's transmission dynamics, established spillover risk factors, and the realistic probability of an outbreak occurring within India. The disease carries a case fatality rate averaging 50%, with documented extremes between 25% and 90%. Transmission occurs through direct contact with the bodily fluids of symptomatic individuals, and key amplifying factors include poor infection prevention practices, unsafe burial customs, and exposure to wildlife, such as fruit bats and non-human primates.

Although India's geographic distance from traditional endemic zones and the absence of established reservoir hosts appear to mitigate immediate risk, the reality of global interconnectedness complicates this picture. High volumes of international travel, coupled with the unpredictable nature of evolving zoonotic transmission patterns, ensure that the threat of introduction remains tangible rather than theoretical. In the event of emerging cases, India's Integrated Health Information Platform (IHIP), operating under the Integrated Disease Surveillance Programme, alongside Rapid Response Teams, would be placed under considerable operational strain. The sheer scale and speed of potential outbreaks could overwhelm existing mechanisms, exposing vulnerabilities in coordination, diagnostic reach, and response agility.

Against this backdrop, strengthening surveillance infrastructure, expanding laboratory capacity, and refining preparedness protocols cannot be dismissed as mere precautionary measures. They are indispensable pillars of national health security. Enhanced real-time data integration, robust genomic sequencing networks, and scalable rapid response units are critical to ensuring resilience. Equally important are simulation exercises, stockpiling essential medical supplies, and establishing clear communication strategies to counter misinformation. In essence, India's preparedness must evolve from reactive containment to proactive resilience, recognizing that in a globalized era, geographic distance offers only partial protection while systemic readiness provides the true safeguard.

Keywords: Ebola Virus Disease, Epidemiology, Zoonotic Spillover, Disease Surveillance, India, IDSP, Public Health Preparedness

Introduction

Ebola virus disease (EVD), formerly known as Ebola hemorrhagic fever, is one of the most severe and life-threatening infectious diseases affecting both humans and non-human primates. The disease first came to global attention in 1976 following two simultaneous outbreaks, one in Nzara, Sudan, and the other in Yambuku, Democratic Republic of Congo (DRC). Since then, recurrent outbreaks have been reported across Central and West Africa, culminating in the devastating 2014-2016 West African epidemic, which remains the largest and deadliest EVD outbreak recorded to date.[1,2]

The World Health Organization (WHO) has always seen EVD as a serious public health threat because it can spread easily, has a high death rate, and there are not many effective ways to prevent or treat it.[3] The global threat re-emerged in May 2026, when a multi-country outbreak involving Uganda and the DRC prompted the WHO to declare a global health emergency. Although India has not reported any confirmed cases, the Government of India responded by issuing a nationwide advisory for travelers and individuals with links to affected regions, acknowledging Ebola is no longer a distant public health concern and is considered among the country's top ten viral threats.[4]

This article provides a structured assessment of the potential risk posed by EVD in the Indian context. It examines the epidemiology of the disease, established transmission dynamics and spillover risk factors, a realistic appraisal of the likelihood of an outbreak in India, and the potential implications for the country's public health system should confirmed cases be detected.

Epidemiology of Ebola Virus Disease

Case Definition and Classification

With a sudden onset of high fever (≥38.6°C) within the preceding 21 days, who has had contact with a confirmed or probable case, a deceased individual, or alive or dead animal in an endemic area are defined as case. A probable case is one that meets the clinical criteria for hemorrhagic manifestations or unexplained death or yields a positive preliminary laboratory result. Laboratory confirmation of EVD requires one of the following diagnostic methods: polymerase chain reaction (PCR), antigen-capture enzyme-linked immunosorbent assay (ELISA), or immunohistochemistry.[5]

Taxonomically, the Ebola virus belongs to the genus *Orthoebolavirus* within the family *Filoviridae*. Six distinct species have been identified: *Zaire*, *Sudan*, *Bundibugyo*, *Taï Forest*, *Reston*, and *Bombali*. Among these, the *Zaire* species has been responsible for the major and most severe human outbreaks. The *Sudan* and *Bundibugyo* species are also associated with clinically severe disease. In contrast, the *Reston* and *Bombali* species have demonstrated limited pathogenicity in humans, with *Reston* notably capable of infecting humans without causing clinically significant illness.

Clinical Features and Mortality

The incubation period ranges from 2 to 21 days, during which infected individuals remain asymptomatic. Clinical illness typically begins with non-specific symptoms, including fever, fatigue, myalgia, headache, and pharyngitis, and subsequently progresses to vomiting, diarrhoea, rash, and renal and hepatic dysfunction. In severe cases, both internal and external haemorrhage may occur, presenting as gingival bleeding, haematemesis, haematochezia, and bleeding from venipuncture sites.[6,7] Early clinical manifestations frequently overlap with those of malaria, typhoid fever, and bacterial meningitis, posing significant diagnostic challenges, particularly in resource-limited settings.

Mortality rates vary considerably across outbreaks. The overall case fatality rate (CFR) averages approximately 50%, although reported estimates range from 25% to 90%, depending on the viral species involved and the epidemiological context of the outbreak.[7,8] *Zaire ebolavirus* has historically been associated with the highest CFR (80-90%), whereas *Bundibugyo ebolavirus* has demonstrated case fatality rates below 50% in recent outbreaks. Death most commonly results from hypovolemic shock and multi-organ failure rather than haemorrhage itself and typically occurs within 6-16 days following symptom onset.[6]

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Transmission Dynamics

Zoonotic Spillover

EVD is fundamentally a zoonotic disease. Fruit bats of the *Pteropodidae* family are widely considered the most likely natural reservoir of the Ebola virus, although this has not yet been definitively established.[9] Human infection is typically initiated through direct contact with or handling of infected wildlife, particularly fruit bats, chimpanzees, gorillas, forest antelopes, and porcupines, especially when these animals are sick, found dead, or encountered within dense forest habitats.[2,10]

African great apes are not true reservoir hosts; instead, they develop severe disease and frequently die following infection, indicating that they function as amplifying hosts rather than natural reservoirs. Ecological studies have further demonstrated that the risk of zoonotic spillover is highest during seasonal transitions between the dry and wet periods, when changes in bat foraging behaviour increase opportunities for human-wildlife interactions and subsequent viral transmission.[11]

Human-to-Human Transmission

Once zoonotic spillover has occurred, human-to-human transmission takes place through direct or indirect contact with the blood, saliva, urine, faeces, or other bodily fluids of individuals with symptomatic infection.[7,9] Individuals infected with the virus but who have not yet developed clinical symptoms are considered non-infectious, a characteristic that distinguishes EVD from many respiratory pathogens. Likewise, the virus is not transmitted through air, food, or water.

Established routes of transmission include direct contact with infected bodily fluids, exposure to contaminated fomites such as bedding or clothing, caregiving for infected family members, participation in unsafe burial practices, and exposure within healthcare settings where infection prevention and control (IPC) measures are inadequate.[13] During the West African Ebola epidemic, healthcare workers were disproportionately affected, primarily because of inadequate personal protective equipment (PPE), limited isolation capacity, and suboptimal implementation of IPC protocols.[12]

Two additional transmission-related considerations warrant attention. First, Ebola virus RNA has been detected in semen for up to seven weeks following clinical recovery, posing a potential risk of sexual transmission among survivors. Second, breast milk from infected mothers may serve as a source of transmission to breastfeeding infants. Outside the human body, the virus is relatively unstable and survives for only approximately 30 seconds under ambient air conditions, substantially limiting the likelihood of airborne transmission.[12,13]

Outbreak History

Since its identification in 1976, the majority of EVD outbreaks have occurred in Central Africa, particularly in the DRC, Uganda, and Sudan. The 2014-2016 West African epidemic represented a notable epidemiological anomaly, as a region with no previous history of Ebola became the epicentre of the largest EVD outbreak ever recorded. The epidemic resulted in more than 11,000 deaths among nearly 28,000 documented cases.[15] Although the outbreak was officially declared over in June 2016, sporadic flare-ups continued to occur in subsequent years.

More recent outbreaks have been reported in the DRC between 2018 and 2022 and in Uganda during 2023 and 2024-2025, underscoring the persistent circulation of the Ebola virus in Central Africa and its continued public health significance. Importantly, despite the extensive international travel associated with the 2014-2016 epidemic, no confirmed cases of EVD have ever been reported in Asia.[13]

Known Risk Factors for Spillover and Transmission

Environmental and Ecological Drivers

Ecological modelling has consistently identified temperature seasonality and population density as the two principal environmental determinants of Ebola virus spillover risk.[11] In Central Africa, spillover risk remains relatively stable throughout the year, whereas East and West Africa exhibit more pronounced seasonal variation associated with fluctuations in rainfall patterns. Forest-savanna transition zones have been identified as particularly high-risk landscapes, as they provide ecological conditions that facilitate bat-human interactions.[16]

Future climate projections indicate a 1.75- to 3.2-fold increase in animal-to-human spillover rates across Africa by 2070. Under scenarios characterised by rapid population growth and slower socioeconomic development, this risk is expected to increase further, with the probability of an epidemic rising by up to 1.63-fold per spillover event.[17,18] Collectively, these projections indicate that the risk of Ebola virus spillover is dynamic and likely to increase over time.

Behavioural and Occupational Factors

Hunting and preparation of bushmeat, particularly from non-human primates and bats, have been consistently identified as early-stage spillover risk factors. Communities that depend on subsistence hunting are at increased risk of direct occupational exposure, especially during the handling

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and processing of animal carcasses without appropriate personal protective equipment.[2,10] Although thorough cooking to a core temperature exceeding 70°C substantially reduces the risk of foodborne transmission, it does not completely eliminate the overall dietary risk associated with bushmeat consumption.

Funeral and burial practices have also played a significant role in facilitating community-level transmission. During several African outbreaks, ritual washing of the deceased and direct physical contact with bodies during burial ceremonies resulted in exposure to highly infectious bodily fluids among mourners. As these practices are deeply rooted in cultural and social traditions, effective risk mitigation requires culturally sensitive community engagement and the establishment of trust rather than solely relying on public health directives.[15]

Healthcare System Weaknesses

The West African Ebola epidemic exposed the catastrophic consequences of inadequately prepared health systems. Healthcare-associated transmission intensified as healthcare facilities lacked adequate isolation capacity, appropriate Personal Protective Equipment (PPE) stockpiles were depleted, healthcare workers were insufficiently trained in appropriate donning and doffing procedures, and general wards continued to admit febrile patients without systematic screening for EVD.[15,17] Consequently, healthcare facilities intended to provide treatment became major sites of disease amplification. In some of the states in India, the health conditions and facilities are similar to Africa.

Beyond the direct impact of EVD transmission, the epidemic imposed a substantial indirect burden on population health. An estimated 10,600 additional deaths occurred across Guinea, Liberia, and Sierra Leone as a result of disruptions to essential health services, including routine immunization, maternal healthcare, and tuberculosis and malaria programmes.[13] This pattern of collateral mortality underscores a critical lesson for countries developing EVD preparedness and response strategies.

Structural and Socioeconomic Barriers

In West Africa, the response was further undermined by structural inequities, including fragile public health systems, deep-rooted distrust of government health authorities, and limited community familiarity with the clinical presentation of EVD. These factors contributed to delays in case identification, low voluntary uptake of diagnostic testing, and resistance to quarantine measures.[13] In addition, porous international borders and extensive informal trade networks facilitated the geographic spread of the disease. These challenges are not unique to Africa; rather, they are relevant to any setting where public trust in health systems is limited.

Risk Assessment: Could an Ebola Outbreak Occur in India?

Factors That Lower Endemic Risk

Several biological and ecological factors make sustained endemic transmission of EVD in India highly improbable. India is home to 127 bat species; however, the bat species identified as primary reservoirs of the Ebola virus all belonging to the family Pteropodidae, are largely confined to Central and West Africa and are not found in India.[18] Furthermore, African great apes, recognized as important amplifying hosts during zoonotic transmission, are absent from the Indian subcontinent. India's monsoon-driven ecosystems and forest composition differ substantially from the tropical forest environments of Central and West Africa, where most documented spillover events have occurred. Consistent with these ecological differences, environmental suitability models indicate that South Asia provides limited conditions for sustained Ebola virus circulation.[19] Additionally, the consumption of wild bat and non-human primate meat is not a culturally established practice in India, thereby eliminating a major dietary exposure pathway associated with zoonotic transmission.

Factors That Increase Importation Risk

Despite low endemic risk, the potential for disease importation presents a distinct public health concern. During the 2014-2016 epidemic, India ranked 13th globally among destinations for travellers departing Guinea, Liberia, and Sierra Leone.[20] As a major international aviation hub receiving millions of inbound travellers annually, India remains meaningfully exposed to individuals who may be within the 2-21-day incubation period of EVD. An infected traveller arriving from an outbreak-affected region could inadvertently expose household contacts, healthcare workers, or fellow passengers before symptom onset prompts clinical suspicion.

This risk is further compounded by operational vulnerabilities within the public health system. India's disease surveillance system has an average outbreak detection lag of 7-10 days, which is suboptimal for a rapidly evolving pathogen such as EVD. In addition, the quality of disease reporting varies considerably across states, biosafety level-4 (BSL-4) laboratory capacity remains limited and geographically concentrated, and IPC infrastructure outside major tertiary care centres is inconsistent.[18,21] The Central Union Health Ministry is already alerted for preparedness which demanded Point of Entry surveillance, capacity building, and stockpiling logistic[s]

Probability Estimates

Drawing on the available epidemiological evidence, the probability of endemic wildlife spillover of EVD in India is

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considered to be extremely low (<0.1%). In contrast, the probability of at least one imported case during an active outbreak in Africa is estimated to be low to moderate (10-30%), depending on the magnitude of the outbreak and prevailing international travel patterns. Following the introduction of an imported case, the probability of sustained secondary transmission is estimated to be low (5-15%), contingent upon the timeliness of case detection, the effectiveness of IPC measures within healthcare settings, and the level of public cooperation with public health interventions.

Overall, although the likelihood of a large-scale EVD epidemic in India is low, it cannot be considered negligible. The transition from successful containment to sustained outbreak would depend primarily on the speed of case recognition, prompt isolation, and the rapid implementation of appropriate public health response measures.

Impact on India's Health Systems if Cases Are Confirmed

Disease Surveillance Activation

Confirmed EVD cases would immediately trigger activation of India's Integrated Disease Surveillance Programme (IDSP), a decentralized laboratory-based surveillance system operational since 2004.[21] Routine passive surveillance would transition to intensive, real-time case detection, with the acceptable interval between case occurrence and detection reduced from the current 7-10 days to less than 48 hours. Rapid Response Teams from the National Centre for Disease Control and state health departments would be deployed to undertake field investigations, contact tracing, and implementation of containment measures. Given India's limited BSL-4 laboratory capacity, international collaboration with WHO and CDC reference laboratories would likely be required for confirmatory diagnostics and specialized laboratory support.

Although the IDSP has evolved substantially since its inception, its operational capacity would be considerably challenged by simultaneous multi-state transmission, a scenario that cannot be excluded in view of India's high population density and extensive urban connectivity.

Healthcare Infrastructure Demands

Treatment Units with negative-pressure isolation capacity would need to be rapidly established in tertiary care centres, representing a requirement that extends well beyond the COVID-19 isolation wards implemented in most healthcare facilities.[22] Substantial quantities of full-body PPE, powered air-purifying respirators (PAPRs), and biosafety consumables would be required to ensure safe clinical management. During the West African epidemic, healthcare worker infection rates reached 25-30% in some facilities, highlighting the consequences of inadequate training, insufficient supplies, and suboptimal infection prevention protocols. India would therefore need to implement these measures rapidly and comprehensively to prevent similar outcomes, while simultaneously mitigating the inevitable disruption to routine healthcare services.

Communication and Social Dynamics

Public trust would likely come under immediate strain during an Ebola outbreak. Social media platforms would facilitate the rapid dissemination of both accurate information and misinformation, necessitating coordinated, real-time risk communication by public health authorities. Experiences from Ebola outbreaks in Africa have demonstrated that survivors may face stigma, employment discrimination, and social exclusion dynamics that could similarly emerge in India in the absence of proactive community engagement and robust psychosocial support systems. Further, India's linguistic and cultural diversity would require multilingual, culturally tailored communication strategies that leverage established community networks, including ASHA workers, local leaders, and faith-based organizations.

Economic Consequences

The economic impact of even a contained EVD outbreak would be substantial. Direct costs, including the establishment of isolation facilities, diagnostic testing, procurement of PPE, and compensation for healthcare workers, would impose a considerable financial burden. Indirect costs, such as losses in tourism, disruptions to aviation, and reduced workforce productivity, could further amplify the overall economic impact. The West African EVD epidemic resulted in an estimated gross domestic product (GDP) loss exceeding US$2 billion across the three most affected countries, despite not involving a major urban centre comparable in scale to those in India.

Recommended Preparedness Measures

India need not wait for an imported case before strengthening its preparedness. Time to time preparedness exercise is useful for zero mortality.[23] The following measures are scientifically grounded and operationally feasible:

- **Surveillance:** Strengthen the IDSP by enhancing surveillance for acute febrile illness with haemorrhagic manifestations, particularly at points of entry and tertiary healthcare facilities. Implement mobile-based real-time reporting systems to reduce the interval between case detection and notification to less than 48 hours. Expand the cadre of trained field epidemiologists at the district level particularly public health emergencies and disaster management.
- **Laboratory capacity:** Establish regional BSL-4 laboratories across northern, southern, eastern, and western India. Validate reverse transcription polymerase chain reaction (RT-PCR) assays for Ebola

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virus detection and standardise biosafety protocols across all designated reference laboratories.

- **Healthcare readiness:** Designate Ebola Treatment Unit (ETU)-capable facilities in every state. Conduct annual IPC audits across both public and private healthcare institutions. Develop and maintain strategic PPE stockpiles through periodic replenishment and rotation. Establish and regularly rehearse healthcare worker safety protocols, including procedures for occupational exposure and post-exposure management.
- **Coordination and simulation:** Develop a national EVD contingency plan involving the health sector, civil aviation, border security agencies, and other relevant civil authorities. Conduct regular inter-agency simulation exercises to identify operational gaps and strengthen institutional preparedness.
- **Communication:** Develop multilingual public education materials on EVD in advance of any outbreak. Establish systems for real-time monitoring and mitigation of misinformation. Integrate community health workers and local leaders into preparedness planning to promote public trust and facilitate community engagement.

Ebola virus disease (EVD) will remain a persistent global public health threat, and while India's ecological and biological characteristics make sustained endemic transmission highly improbable, the risk of importation during major African outbreaks is real, with probabilities estimated between 10% and 30%. In such circumstances, if an imported case were to enter undetected, the narrow window to prevent secondary transmission could close rapidly, placing immense strain on containment systems.

Conclusion

India's experience during the H1N1 and COVID-19 pandemics demonstrated its remarkable capacity for rapid mobilization and building institutional resilience and infrastructure that now serve as a foundation for future preparedness. The challenge now is to translate these lessons into a targeted EVD strategy. This means strengthening surveillance systems so that early detection is possible through real-time integration of hospital, laboratory, and community-level data, while also incorporating event-based signals from travel hubs and veterinary networks. It requires expanding laboratory capacity so that district-level facilities can provide rapid diagnostics and regional hubs can deliver confirmatory testing, supported by genomic sequencing to track viral evolution. Healthcare worker preparedness must be enhanced through specialized training in infection prevention and control, with clear protocols for isolation, case management, and safe sample transport. At the same time, community engagement is essential: transparent communication, multilingual outreach, and culturally sensitive messaging will build trust and counter misinformation, ensuring compliance with preventive measures. Finally, resource readiness must be ensured by maintaining stockpiles of PPE, antivirals, and rapid deployment kits and by conducting simulation exercises that test response capacity at airports, hospitals, and border points.

The investment required for these measures is modest compared with the catastrophic human and economic costs of an uncontrolled outbreak. Proactive preparedness is therefore not optional but indispensable, and by embedding its COVID-era institutional resilience into a forward-looking strategy, India can mitigate the risks of future EVD importation events and safeguard national health security in an increasingly interconnected world.

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