

# Re-emerging Zoonotic Diseases in India: Insights and Evolving Challenges

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DOI: <https://doi.org/10.62830/mmj2-02-10b>

## Abstract:

The majority of humans interact with animals in some form, creating opportunities for disease transmission. A zoonotic disease is a disease or infection that can be transmitted naturally from vertebrate animals to humans or from humans to vertebrate animals. Common examples include bacterial infections such as salmonellosis, brucellosis, plague, and leptospirosis; fungal diseases like cryptococcosis and histoplasmosis; parasitic infections such as leishmaniasis, hydatid disease, schistosomiasis, and toxoplasmosis; and viral illnesses including rabies, influenza, and yellow fever.

Throughout history, zoonotic pathogens have been responsible for major pandemics, such as the Black Death, the Plague of Justinian, and the 1918 Spanish flu. More recently, the Nipah virus, causing severe encephalitis, and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for the coronavirus disease 2019 (COVID-19) pandemic, are believed to have zoonotic origins. India, with its predominantly agriculture-based economy and high dependence on animal husbandry, faces heightened vulnerability to zoonotic diseases. Other contributing factors, including population growth, urbanisation, deforestation, and inadequate public health infrastructure, all of which pose serious threats. This review aims to examine the landscape of emerging zoonotic diseases in India and underscore the urgent need for integrated One Health approaches in policy and practice.

**Key words:** Zoonotic Diseases, Climate Change, Antimicrobial Resistance.

## Emergence of Zoonotic Disease

According to the World Health Organization (WHO), zoonotic diseases are infections transmitted from animals to humans and can be caused by bacteria, viruses, fungi, or parasites (Table 1).<sup>1</sup> Emerging zoonotic diseases are newly identified infections transmitted from animals to humans that are increasing in

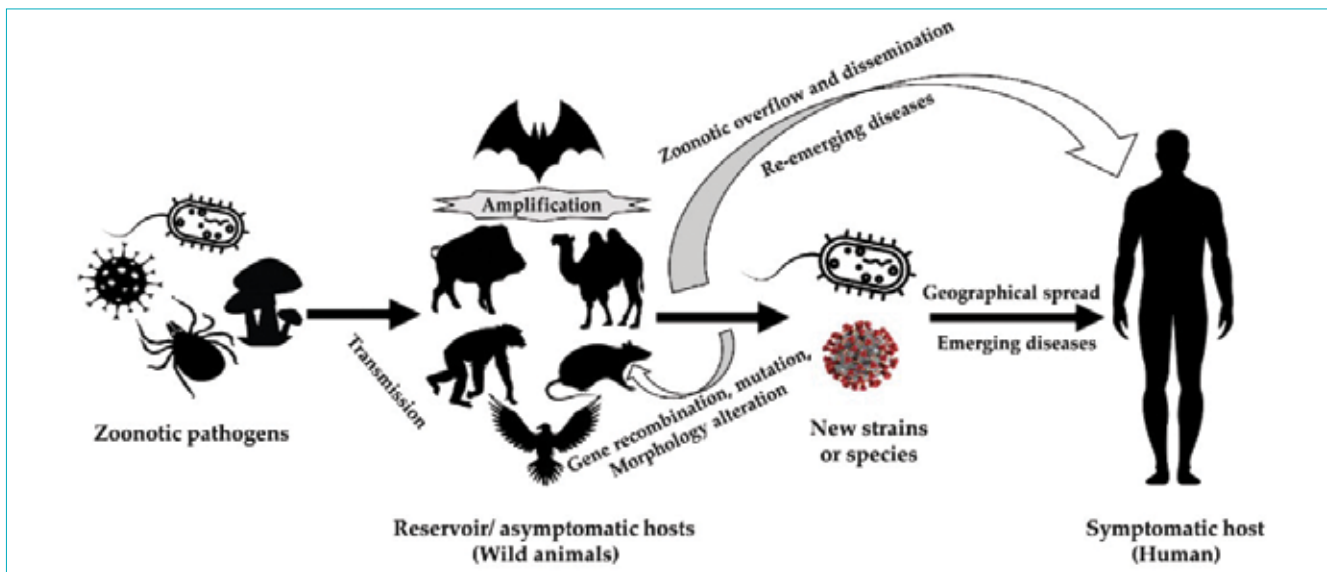
incidence or geographic spread, while re-emerging zoonotic diseases are previously known animal-to-human infections that had declined but are now resurging in incidence or distribution.

Bacterial Pathogens - Hosts	Viral Pathogens - Hosts	Fungal Pathogens - Hosts	Parasitic pathogens
Brucella - Raccoon, hare	Rabies - Dogs, bats	Cryptococcus and histoplasmosis - Bats	Leishmaniasis - Sandfly
Leptospira - Rats, cattle, buffalo	Influenza- Bats, camel		Hydatid disease - Dogs
Salmonella - Poultry and eggs	Dengue and chikungunya - Aedes Mosquito		Schistosoma - Snails
Bubonic plague - Rats	Japanese encephalitis virus - Pond herons, cattle egrets		Toxoplasma - Cats
	Hanta virus - Bandicots, rats, shrews		
	CrimeanCongo haemorrhagic virus - Shrews, bats		
	Kyasanur forest disease virus - Sick/dying monkeys, birds, ticks		

**Table 1:** Classification of zoonotic diseases based on the type of pathogen.<sup>2</sup>

A reservoir host is the one that serves as a source of infection and potential reinfection to animals/humans by harbouring a pathogen, without itself suffering from significant illness. While, an amplifier host is the one in which the pathogen multiplies to high levels, providing an important source of infection for target

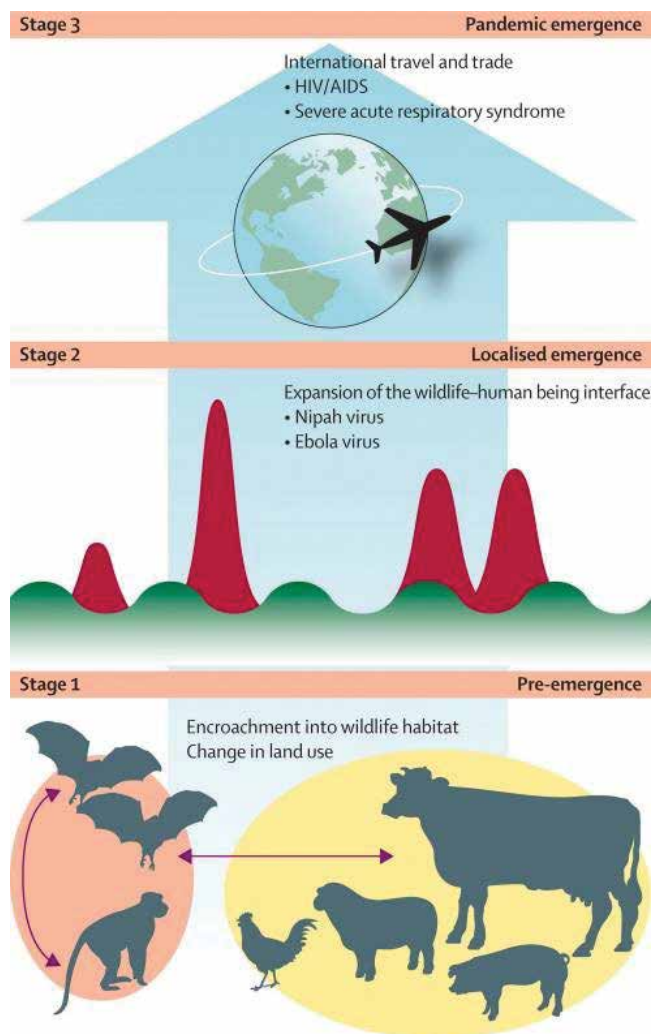
host and vectors. Transmission of pathogen from reservoir or amplifier hosts to humans can occur through various routes such as direct contact, ingestion of contaminated food or water, or via vector organisms (Figure 1).



**Figure 1:** The involvement of the wild animals in the transmission and amplification of aetiological agents of emerging and re-emerging zoonoses.<sup>3</sup>

The unpredictable emergence of zoonotic diseases poses significant challenges for pandemic forecasting. To address this, the Daszak model was proposed<sup>4</sup> which conceptualises zoonotic spillover in three progressive stages (Figure 2).

1. Stage 1 represents the pre-emergence phase, during which microbes circulate within their natural animal reservoirs without infecting humans. ecological disruptions — such as land-use changes — can alter host and microbial dynamics, potentially increasing the risk of spillover to other non-human species, including wildlife and livestock, although not yet to humans.
2. Stage 2 marks localised emergence, characterised by limited spillover events. These may be small and self-limiting (depicted by green peaks and troughs, reflecting fluctuating case numbers over time) or more extensive spillovers (red peaks), leading to short chains of human-to-human transmission.
3. In stage 3, certain spillover events result in sustained human transmission, which can escalate to widespread outbreaks, cross-border dissemination, and ultimately, the development of a true pandemic.



**Figure 2:** Stages of zoonotic spillover.<sup>5</sup>

While the potential impact and geographic reach of each stage increase from stages 1 through 3, the frequency of such events declines, with stage 3 pandemics being relatively rare. For healthcare professionals, it is imperative to understand the factors contributing to the resurgence of zoonotic diseases and to be prepared for the challenges they present.

A detailed understanding of this progression, along with its ecological and epidemiological drivers, can inform more targeted strategies for pandemic prevention. Ideally, effective control measures should aim to intervene at stage 1, preventing pathogens from ever reaching the human population.

## 1. Factors driving the Re-emergence of Zoonoses in India

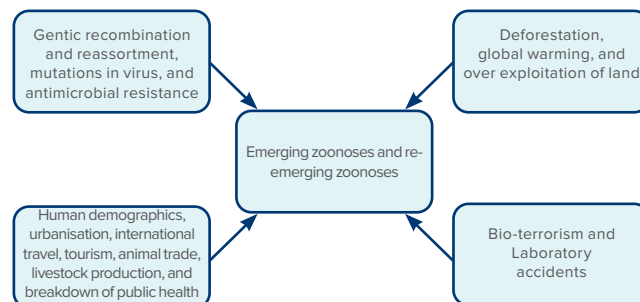
### 1.1. Urbanisation and population growth

India's rapid urbanisation, combined with a burgeoning population, has resulted in increased human-wildlife interactions. This disrupts forest ecosystems and allows previously hidden forest pathogens to enter newly formed human settlements. Examples include diseases like Nipah virus (NIV) and Kyasanur forest disease.<sup>6</sup> Urbanisation, closely linked to population growth, leads to accumulation of waste and poor sanitation. This creates ideal conditions for rodents and stray

animals to thrive and for stagnant water to accumulate — providing breeding grounds for mosquitoes. These factors contribute to the emergence and re-emergence of zoonotic diseases of rodent and arthropod origin, (Figure 3) such as Japanese encephalitis, dengue, and leptospirosis.

### 1.2. Climate change and environmental disruption

Climate change has profound effects on zoonotic disease dynamics. Warmer temperatures, altered



**Figure 3:** Major factors responsible for emerging and re-emerging zoonoses.<sup>3</sup>

precipitation patterns, and changing ecosystems influence the distribution and behaviour of vector species, such as mosquitoes, ticks, and rodents. Diseases like dengue, malaria, and chikungunya, which are transmitted by vectors, are becoming more widespread in India due to shifting climate conditions.<sup>7</sup>

### 1.3. Agricultural practices and livestock management

India's agricultural sector is a key driver of zoonotic disease emergence. The close proximity of humans, livestock, and wildlife increases the chances of disease transmission. Practices such as the intensive farming of poultry, dairy, and other livestock can facilitate the spread of diseases like avian influenza, brucellosis, and tuberculosis. Additionally, the lack of proper veterinary surveillance systems further exacerbates the problem.<sup>8</sup>

### 1.4. Globalisation and movement of people and goods

India's interconnectedness with the global community also poses a significant risk in terms of zoonotic disease spread. The movement of people, animals, and goods across borders facilitates the rapid spread of infectious diseases. The recent outbreaks of coronavirus disease 2019 (COVID-19), originating from animal-human interactions, have demonstrated the vulnerability of human populations to emerging zoonotic threats in a globalised world.<sup>9</sup>

### 1.5. Antimicrobial resistance

Biological factors like mutations in genome of virus, are also a significant factor. Drug-resistant pathogen strains can emerge as a consequence of chemical and antimicrobial agent exposure, making disease management and therapeutic interventions more challenging.<sup>10</sup> The overuse of antibiotics and antivirals in both human and veterinary medicine contributes

to the development of resistant strains of pathogens, complicating therapeutic efforts. Illustrative examples are shown in Table 2.

Disease	Contributing Factor
Middle East respiratory syndrome	Wildlife, travel
Highly Pathogenic Avian Influenza (HPAI) viruses	Animal-animal influenza virus gene reassortment; emergence of H5N1 avian influenza, extensive chicken farming
Ebola virus	Technology and industry developments (healthcare)
Leptospirosis	Developments (Health care)
Severe acute respiratory syndrome	Ecosystem change
Crimean-Congo Haemorrhagic fever	Ecological changes favouring increased human exposure to ticks of sheep and small wild animals
Lassa Fever	Hospital exposure to index case – rodent exposure
Cryptosporidiosis	Inadequate control of water supply, international travel, increased use of child-care facilities
Rabies	Breakdown in public health measures, change in land use, travel, bites from rabid dogs
Rift valley fever	Climate change
Tuberculosis	Drug resistance; Breakdown in public health or control measures

**Table 2:** Some examples of emerging and re-emerging infections and their root cause.<sup>10</sup>

## 2. Key Re-emerging Zoonoses in India

### 2.1. Rabies

Rabies, a viral zoonosis primarily transmitted through the bite of an infected animal, remains a major public health issue in India. Despite advances in vaccination and post-exposure prophylaxis (PEP), India continues to bear a significant rabies burden, accounting for approximately 36% of global rabies deaths, with an estimated 18,000 - 20,000 fatalities annually.<sup>11</sup> Stray dogs, which are abundant in urban and rural areas, are the primary source of rabies transmission. Rabies has a high case fatality rate, and the lack of consistent vaccination campaigns in both dogs and humans contributes to the persistence of the disease.

### 2.2. Nipah virus

NiV, a deadly zoonotic virus from the *Paramyxoviridae* family, is transmitted by Pteropus fruit bats and has caused high-mortality outbreaks in South Asia, including Malaysia, Singapore, Bangladesh, and India. India has seen outbreaks in West Bengal (2001, 2007) and Kerala (2018, 2021), with high fatality rates.<sup>3</sup> First identified in 1998 in Malaysia, NiV spreads to humans via intermediary hosts like pigs or directly through bat-contaminated sources such as date palm sap. NiV infection can cause encephalitis and respiratory distress, with a high mortality rate.<sup>12</sup> Human encroachment into wildlife habitats, intensive farming, and genetic factors contribute to NiV's emergence.

Classified as a potential bioterrorism agent (Centers for Disease Control and Prevention [CDC] category C), NiV prevention requires surveillance, safe pig-rearing, protecting food sources from bats, and limiting habitat disruption.

### 2.3. Scrub typhus

Scrub typhus is a vector-borne zoonotic disease caused by the bacterium *Orientia tsutsugamushi* and is a significant contributor to rickettsial infections worldwide. Each year, nearly one million cases are reported globally, with a notable mortality rate. In 2023, multiple outbreaks were reported across the country, resulting in several fatalities, with Himachal Pradesh and Odisha among the hardest-hit states.<sup>13</sup> The disease typically presents with symptoms such as fever, cough, nausea, headache, breathlessness, and, in some cases, altered sensorium. Around one-third of affected individuals may develop severe multiorgan dysfunction involving the heart, kidneys, lungs, and liver. Its characteristic sign includes an eschar at the site of bite of the vector. Treatment includes twice-daily dose of 100 mg of doxycycline and other supportive therapy.

### 2.4. Leptospirosis

Leptospirosis, a bacterial infection caused by the *Leptospira* species, is another re-emerging zoonosis in India. This disease is transmitted through contact with water or soil contaminated by the urine of infected animals, particularly rodents. Leptospirosis is often associated with flooding, as seen during the monsoon season in states like Kerala, Maharashtra, and Tamil Nadu.<sup>14</sup> The disease presents with flu-like symptoms but can progress to severe liver and kidney damage, haemorrhagic fever, or meningitis in some cases.

### 2.5. Avian influenza (bird flu)

Avian influenza, caused by the H5N1 virus, is another zoonotic threat that has periodically emerged in India. In March 2025, a two-year-old girl in Andhra Pradesh succumbed to H5N1 infection, marking the country's first human fatality from avian influenza in the last four years. The transmission of this virus from poultry to humans, although rare, poses significant public health risks. The outbreaks of avian influenza in poultry farms have caused alarm, particularly with the potential for genetic mutations that might make the virus more transmissible between humans. Efforts to control the spread of bird flu include mass culling of infected poultry and surveillance of migratory birds.

### 2.6. Plague

While the plague is no longer a major threat in many parts of the world, India has experienced several outbreaks in the past, particularly in rural areas. The disease is primarily transmitted through flea bites from infected rodents, and although it has been largely controlled through antibiotics, occasional cases continue to emerge, particularly in states like

Rajasthan.<sup>15</sup> Surveillance and vector control measures remain critical in preventing further outbreaks.

### 2.7 Other zoonotic diseases

Zoonotic diseases, a constant threat to the world, are still underrated in many aspects. COVID-19 emerged as a hazard, leaving a bruise on the planet and an example to humankind about the potential threat zoonotic diseases could cause. Anthrax, brucellosis, bovine tuberculosis, cysticercosis, Japanese encephalitis, echinococcosis, toxoplasmosis, and nontyphoidal salmonellosis are the most significant neglected zoonotic diseases, particularly in India.<sup>16</sup>

Similarly, Zika virus, another zoonotic disease, is due to a virus transmitted by *Aedes aegypti* mosquitoes, which bite during the daytime. This virus was primarily detected in monkeys in the Zika forest in Uganda and gradually appeared in humans with time. Symptoms of this virus include headache, malaise, muscle, and joint pain, fever, rash, and conjunctivitis. Other complications are caused during pregnancy. Infants born with congenital Zika syndrome have microcephaly and other congenital abnormalities. The Zika virus may cause a pregnant woman to be prone to preterm birth and miscarriage. Guillain–Barre syndrome, neuropathy, and myelitis are a few of the neurological symptoms most commonly seen with the Zika virus.

Dengue, the most prevalent arboviral illness in humans, transmitted by female *Aedes* mosquito, is frequently reported in India, especially from July to November. The upsurge of dengue fever is a potential threat to society, and timely treatment is vital to prevent mortality.

The febrile illness known as Kyasanur forest disease is accompanied by haemorrhages. It is brought on by a flavivirus spread through a tick bite. Patients experience symptoms ranging from fever and headaches to myalgia, haemorrhages, and neurological symptoms.

## 3. Diagnostic approaches

The diagnosis of zoonotic diseases requires a combination of clinical suspicion, epidemiological understanding, and laboratory investigations. Therefore, a thorough clinical history, especially regarding animal exposure, is essential for guiding diagnosis.<sup>17</sup>

### 3.1. Diagnostic challenges

The diagnostic challenge lies in differentiating zoonotic diseases from other endemic conditions, particularly in a country like India where multiple infectious diseases circulate simultaneously.

Zoonoses often present with nonspecific symptoms, such as fever, headache, fatigue, and muscle pain, which overlap with many other infectious diseases. For example, leptospirosis and dengue fever both present with acute febrile illness and may show overlapping clinical features like headache, muscle pain, and fatigue.

Similarly, malaria and typhoid fever are common in endemic areas and can mimic symptoms of zoonotic diseases like brucellosis or rickettsial infections.

The key to distinguishing between zoonotic infections and other differential diagnoses lies in:

1. **Clinical clues:** It is crucial to inquire about recent travel to areas with known outbreaks, exposure to animals (including domestic pets, livestock, and wildlife), consumption of undercooked meat, or exposure to vectors like mosquitoes or ticks. The patient's occupation — whether they are involved in farming, veterinary work, or wildlife conservation — also provides important clues. Knowing if the patient has been exposed to water sources potentially contaminated by animal urine or faeces can also guide diagnosis, especially for leptospirosis.<sup>18</sup>
2. **Laboratory testing:** Rapid antigen tests, polymerase chain reaction (PCR), and serological assays are essential tools for confirming zoonotic diseases. For instance:
  - o PCR-based assays can detect specific pathogen DNA or RNA, which is useful for diagnosing viral diseases like NiV, Hantavirus, and avian influenza.
  - o Serological tests to detect antibodies (IgM or IgG) against pathogens like *Brucella*, *Leptospira*, or *Rickettsia* help confirm infection.
  - o Blood cultures in cases of leptospirosis or rickettsial infections and urinary antigen tests for *Leptospira* are particularly important.

### 3.2. Syndrome-based approach to diagnosis

A physician should consider zoonotic diseases in the differential diagnosis while evaluating a patient. For instance:

- **Fever of unknown origin (FUO):** In a country like India, where diseases such as tuberculosis, malaria, and typhoid are endemic, FUO is a common presentation. However, if a patient has a history of animal exposure, zoonotic infections like brucellosis, leptospirosis, dengue, or rickettsial diseases should be high on the differential.<sup>18</sup>
- **Acute encephalitis:** In a patient presenting with acute encephalitis, particularly with a history of exposure to bats or other animals, must be considered. Patients with Nipah can present with rapidly progressing encephalitis, requiring immediate isolation and management.
- **Acute respiratory distress:** In patients presenting with severe respiratory distress and a history of rodent exposure, Hantavirus pulmonary syndrome should be considered. Similarly, avian influenza should be considered in patients with a history of close contact with infected poultry.

- **Muscle pain and hepatic involvement:** In patients presenting with muscle pain and evidence of hepatic involvement (elevated liver enzymes, jaundice), leptospirosis should be considered, especially if there's a history of exposure to contaminated water during flooding or water sports.

#### 4. Treatment approaches in Zoonotic Diseases

The treatment plan will depend on the type of pathogen, its severity, and the patient's overall condition. Some zoonotic diseases are treatable with antibiotics, antivirals, or supportive care, while others may require more intensive interventions.

##### 4.1. Antibiotic therapy for bacterial zoonoses

- **Brucellosis:** This is a major zoonotic bacterial infection, especially in India, where patients may present with fever, arthralgia, and splenomegaly. A combination of doxycycline (100 mg twice daily) and rifampin (10 mg/kg/day) for at least 6 weeks is recommended, with possible extension depending on the severity and complications such as osteoarticular or genitourinary involvement.<sup>19</sup>
- **Leptospirosis:** This often presents with a mild or moderate febrile illness but can progress to severe disease with liver failure, kidney damage, or haemorrhagic manifestations. For mild cases, oral doxycycline (100 mg twice daily for 5–7 days) may be sufficient. However, for severe cases, intravenous penicillin G (24 million units/day) or ceftriaxone is indicated.<sup>17</sup>
- **Rickettsial infections (e.g., scrub typhus, Rocky Mountain spotted fever):** The treatment of choice is doxycycline (100 mg twice daily for 7-10 days). Early antibiotic therapy is essential to prevent complications like organ failure or death.<sup>18</sup>
- **Tularemia and plague:** Though these diseases are relatively rare in India, both can be life-threatening and require aggressive antibiotic treatment. Streptomycin or gentamicin are used for tularemia, and streptomycin or doxycycline for plague.<sup>19</sup>

##### 4.2. Antiviral therapy for viral zoonoses

- **NiV:** For Nipah virus, there is no specific antiviral treatment, but supportive care is crucial. Intensive care management, including mechanical ventilation, is often required for patients with respiratory failure or encephalitis.

- **Avian Influenza (H5N1):** Early antiviral treatment with oseltamivir (75 mg twice daily for 5 days) can help reduce mortality and morbidity. However, the emergence of antiviral-resistant strains remains a significant challenge.<sup>17</sup>

##### 4.3. Symptomatic and supportive care

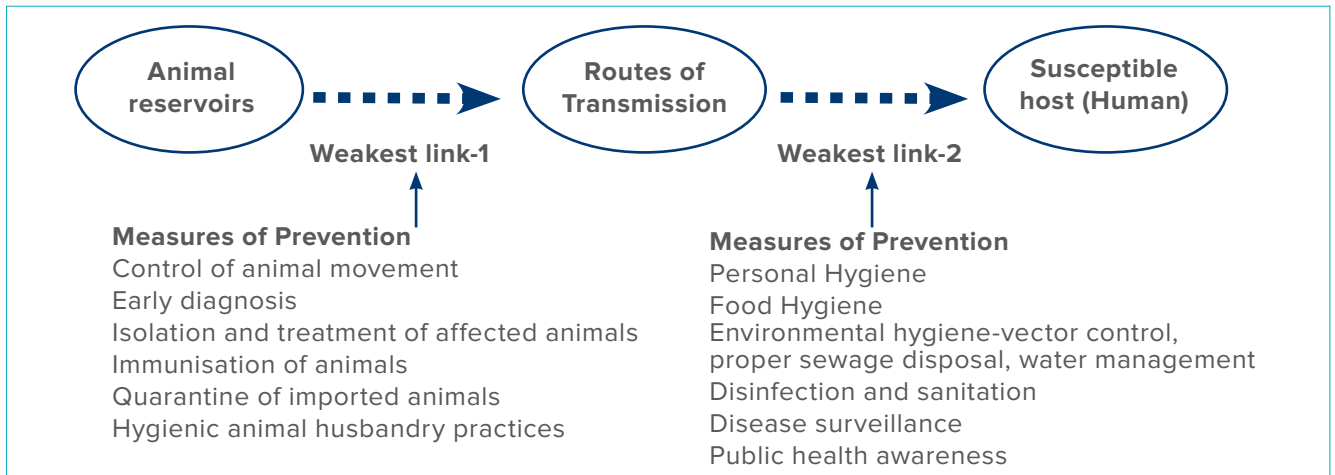
Many zoonotic diseases require extensive supportive care, especially those with multisystem involvement. This includes managing electrolyte imbalances, hydration, and organ support (especially renal and hepatic support). For diseases like leptospirosis, scrub typhus, and malaria, early supportive care can reduce complications and improve outcomes.

- **Hydration and electrolyte management:** In patients with leptospirosis or scrub typhus, especially those with renal or hepatic dysfunction, careful fluid management is essential to prevent acute kidney injury (AKI) or hepatic failure.
- **Ventilatory support:** For patients with severe respiratory involvement due to Hantavirus pulmonary syndrome, NiV, or avian influenza, timely initiation of mechanical ventilation and oxygen therapy can be life-saving.
- **Post-exposure prophylaxis (PEP):** There is role of PEP in some zoonotic diseases. For example, rabies requires immediate administration of the rabies vaccine and immunoglobulin (RIG) following exposure to a potentially rabid animal.

#### 5. Prevention and Control Strategies

The control of emerging zoonotic diseases is often hindered by a limited understanding of how these diseases are transmitted. Additionally, there are significant gaps in knowledge about the role animals play in the emergence of such diseases, as efforts typically focus on treating human cases rather than addressing the animal reservoirs. Effective prevention and control strategies must target the weakest links in the transmission chain — this includes managing animal reservoirs, interrupting transmission pathways, and immunising vulnerable human populations. (Figure 4).

Although most emerging diseases originate from animals, research in human and animal health is often carried out separately. To effectively predict, prevent, and manage emerging zoonotic diseases, there is a need for a unified, multidisciplinary approach. The 'One Health' strategy, which brings together experts in human, animal, and environmental health, offers a comprehensive solution to address these complex and interconnected public health threats.



**Figure 4:** Measures for prevention at the weakest link for blockage of the Transmission.<sup>3</sup>

### 5.1. Implementing the One Health approach

One Health framework recognises the interconnectedness of human, animal, and environmental health, emphasising the need for collaboration between healthcare professionals, veterinarians, environmental scientists, and policymakers. For clinicians, this holistic approach involves understanding the role of animal reservoirs, vector species, and environmental factors in the transmission of zoonotic pathogens.<sup>20</sup>

In India, a concerted effort to adopt One Health strategies is still in embryonic stages.<sup>16</sup> The government initiated the National One Health Mission with the assistance of the Ministries of Health, Agriculture, and Environment. This mission aims to enhance disease surveillance, promote intersectoral cooperation, and strengthen response systems.

Initiatives such as the Integrated Disease Surveillance Programme (IDSP) and the National Animal Disease Reporting System (NADRS) are also enhancing early warning systems. Research institutions such as the Indian Council of Medical Research (ICMR) and the Indian Council of Agricultural Research (ICAR) are working to research on zoonotic diseases.

But One Health must do more. Wildlife health needs to be incorporated into surveillance, and environmental monitoring needs to improve. Health workers and veterinarians must be trained to identify early symptoms of zoonotic diseases. Livestock vaccination programs and rural hygiene practices have to be enhanced. Public awareness campaigns in high-risk regions can prevent outbreaks from spreading. (Figure 5).



**Figure 5:** Schematic representation of One Health approach.<sup>21</sup>

### 5.2. Enhanced diagnostic capacities

One of the biggest challenges is the lack of reliable and rapid diagnostic tools for zoonotic diseases. Clinicians in India, particularly in rural or under-resourced areas, often struggle to identify zoonotic infections accurately and promptly due to limited diagnostic capabilities. The reliance on clinical signs alone can lead to misdiagnosis, which is particularly concerning for diseases with overlapping symptoms, such as leptospirosis, malaria, and dengue fever.

The implementation of improved diagnostic tools, such as PCR-based assays and rapid antigen tests, is crucial to ensure quick and accurate diagnosis. Furthermore, making these diagnostic tools more accessible to healthcare providers in both public and private settings, especially in rural areas, would drastically improve the outcome for patients.

### Conclusion

The re-emergence of zoonotic diseases in India presents a complex challenge that requires a multifaceted approach, one that involves healthcare professionals, veterinarians, environmental scientists, and policymakers working in unison. From a clinician's perspective, there is a need for heightened awareness, improved surveillance, better diagnostic tools, and public education. With India's rich biodiversity and increasing urbanisation, the risks of zoonotic disease outbreaks are significant. However, with strong interdisciplinary collaboration and a commitment to implementing One Health principles, we can mitigate these risks and safeguard public health for future generations.

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**DOI:** <https://doi.org/10.62830/mmj2-02-10b>

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