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Review Article

A Systemic Review on Major Viral Diseases: Causing Agents, Transmission, Control Strategies, and Impact on Human Health

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Abstract

In the 21st century, the virus borne diseases are one of the significant threats to worldwide human health. The major viral pathogens affecting humans with specific impacts on arboviruses (Zika, chikungunya, dengue), respiratory viruses (respiratory syncytial virus, coronaviruses, influenza), persistent viral infections (viral hepatitis, HIV), and haemorrhagic fever viruses (Lassa, Marburg, Ebola). We analyse and address different causative viruses, transmission, control, precaution and various impacts on human and society. We make recent evidence on zoonotic infestation mechanism, role of humans in viral infections, and the importance of the One Health approach in pandemic prevention. Even though significant advances in genomic surveillance, diagnostic technologies, and the development of vaccines, including mRNA vaccines, substantial challenges persist in ensuring equitable access to countermeasures, particularly in low- and middle-income countries. This review helps to understand the complex relationship between viral pathogens, human hosts, and environmental factors, which is essential for developing effective prevention strategies and strengthening global health security against future viral threats.

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INTRODUCTION

Those infections, which have recently appeared in human populations or are increasing the incidence or geographic range, are called as "emerging infectious diseases" (EIDs). The EIDs are zoonotic, arising from viral pathogens that cross species barriers from animals to humans and after 70s, more than 40 novel human viral pathogens have been identified such as Ebola virus, chikungunya virus, Zika virus, SARS (Severe Acute Respiratory Syndrome), MERS (Middle East Respiratory Syndrome), pandemic H1N1 influenza, and most recently SARS-CoV-2. The HIV/AIDS pandemic further reshaped global infectious disease patterns, reversing earlier declines in mortality in many regions (Asokan, *et. al*., 2026).

The 21th century has witnessed repeated emergence of high-impact viral diseases, representing how rapidly novel pathogens can overwhelm public health systems. These events have intensified global recognition of the need for vigilant surveillance and rapid response to emerging and re-emerging threats, particularly those of zoonotic origin (Liu, *et. al.,* 2025). This review synthesizes current knowledge on major viral diseases affecting humans, examining their causative agents, transmission mechanisms, control strategies, and the multifaceted impact on human health and society.

Arboviruses

Arboviruses (arthropod-borne viruses) like Dengue, Zika, Chikungunya, and West Nile represent a growing global health threat, with geographic expansion driven by urbanization, climate change, and increased travel (Parums, 2025).

i). Dengue Virus

Dengue virus is a flavivirus with four distinct serotypes (DENV 1-4). Infection with one serotype confers lifelong immunity to that serotype but only partial and transient protection against others (Ross, 2010).

- **Transmission**

It is transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes. These mosquitoes are day-biting and thrive in urban environments, breeding in small containers of water (Getachew, *et. al.,* 2015). Transmission is expanding geographically as climate change enables mosquito vectors to colonize new regions.

- **Control Strategies**

Vector control remains the primary strategy, including elimination of mosquito breeding sites, insecticide use, and personal protective measures. A dengue vaccine (Dengvaxia) is available but recommended only for individuals with prior dengue infection due to safety concerns in seronegative recipients (Paz-Bailey, et al., 2021). Novel vaccines and antiviral therapies are under development.

- **Impact on Humans**

It is the most rapidly spreading mosquito-borne viral disease, with an estimated 100-400 million infections annually. Severe dengue can cause plasma leakage, shock, and death, especially in children (Ulgheri *et. al.,* 2025).

ii). Zika Virus

It is a flavivirus closely related to dengue. While most infections are asymptomatic or cause mild illness, the virus gained notoriety due to its association with severe congenital abnormalities.

- **Transmission**

It transmitted primarily by *Aedes mosquitoes*. However, it can also be transmitted sexually, vertically from mother to foetus, and through blood transfusion, distinguishing it from other arboviruses (Wong, *et. al.,* 2025).

- **Control Strategies**

Prevention focuses on mosquito control and personal protective measures. During pregnancy, avoiding travel to areas with active transmission and practicing safe sex are recommended. No specific antiviral treatment or vaccine is currently available.

- **Impact on Humans**

The 2015-2016 Zika epidemic in the Americas revealed the capacity of virus to cause congenital Zika syndrome, including microcephaly and other severe brain abnormalities in infants born to infected mothers. The outbreak caused widespread concern and led to declarations of a Public Health Emergency of International Concern (WHO, 2025).

iii). Chikungunya Virus

It is an alphavirus transmitted by *Aedes mosquitoes*. Term Chikungunya derived from a Makonde word describing the contorted posture of patients with severe joint pain.

- **Transmission**

Its transmission occurs through the bite of infected *Aedes aegypti* and *A. albopictus* mosquito species. The urban transmission cycle involves human-mosquito-human transmission without requiring animal reservoirs (Henderson Sausa, *et. al.,* 2023).

- **Control Strategies**

Vector control is the primary prevention strategy. No specific antiviral treatment or licensed vaccine is currently available, though vaccine candidates are in development.

- **Impact on Humans**

Chikungunya causes acute febrile illness with severe, often debilitating polyarthralgia that can persist for months or years. Large outbreaks have occurred in Asia, Africa, the Indian Ocean islands, and the Americas, causing substantial morbidity and economic disruption (Bartholomeeusen, *et. al.,* 2023).

iv). West Nile Virus

West Nile virus is a flavivirus maintained in an enzootic cycle between birds and mosquitoes.

- **Transmission**

It is transmitted primarily by female *Culex* mosquitoes, with birds serving as the natural reservoir. Humans and horses are incidental or "dead-end" hosts, as they do not develop sufficient viremia to infect feeding mosquitoes (Bruno, *et. al.,* 2025).

- **Control Strategies**

Prevention focuses on mosquito control programs and personal protective measures. Blood donation screening helps prevent transfusion-related transmission. No human vaccine is currently available.

- **Impact on Humans**

Since its introduction to North America in 1999, West Nile virus has become the leading cause of domestically acquired arboviral disease in the US. While most infections are asymptomatic, approximately 1% develop neuroinvasive disease (encephalitis or meningitis) with high mortality and long-term sequelae in survivors (Marino, *et. al.,* 2025).

Respiratory Viral Infections

Respiratory viral infections represent a major global public health challenge, contributing significantly to morbidity and mortality, specially in vulnerable populations such as children under five, the elderly, and those with comorbid conditions. The coronaviruses, respiratory syncytial virus (RSV), and Influenza are major respiratory infection virus.

i). Coronaviruses (SARS-CoV-2, SARS-CoV, MERS-CoV)

These are large positive-sense RNA viruses (approximately 26-32 kb) belonging to the Coronaviridae family. They are distinguished by their club-shaped spike proteins, which give them a crown-like appearance and exist in four varients like Alpha, Beta, Gamma, and Delta, out of which only alpha and beta coronaviruses infecting humans. Three highly pathogenic coronaviruses have emerged in the 21th century are SARS-CoV (2002-2003), MERS-CoV (2012-present), and SARS-CoV-2 (2019-present), the causative agent of COVID-19 (Chathapaddy House, *et.al*., 2021).

- **Transmission**

Coronaviruses are primarily transmitted through respiratory droplets and aerosols, with SARS-CoV-2 representing particular efficiency in airborne transmission. The virus infects the upper respiratory tract and can be coughed into the air, surviving sufficiently to spread to other humans. Transmission can also occur through contact with contaminated surfaces and, for some coronaviruses, through faecal-oral routes. The basic reproduction number for SARS-CoV-2 was initially estimated at 2-3, though more transmissible variants have emerged with higher R_0 values (Manathunga, *et. al.,* 2023).

- **Control Strategies**

Control measures for coronaviruses have evolved substantially since the emergence of SARS-CoV-2. Non-pharmaceutical interventions including masking, physical distancing, improved ventilation, and isolation of infected individuals have proven essential, particularly before vaccines became available. The rapid development and deployment of multiple vaccine platforms, particularly mRNA vaccines, represented a historic scientific achievement. Antiviral medications including remdesivir and nirmatrelvir-ritonavir, as well as immunomodulatory agents such as corticosteroids for severe disease, have improved clinical outcomes (Alves, *et. al.,* 2025).

- **Impact on Humans**

The COVID-19 pandemic has caused unprecedented global health, social, and economic disruption. As of 2025, the virus has caused millions of deaths globally and continues to circulate with new variants complicating the global response. The pandemic exposed vulnerabilities in healthcare systems worldwide, particularly in low- and middle-income countries, and highlighted global inequities in access to vaccines and therapeutics (De Gaetano, *et. al.,* 2025). Beyond acute mortality, SARS-CoV-2 infection is associated with long-term sequelae ("long COVID") affecting multiple organ systems.

ii). Influenza Viruses

These are members of the Orthomyxoviridae family and are classified into types A, B, C, and D. Influenza-A viruses are further subtyped based on the surface glycoproteins haemagglutinin (HA) and neuraminidase (NA), with multiple subtypes circulating in aquatic birds, which serve as the natural reservoir. The virus is characterized by its high mutation rate and capacity for genetic reassortment, which enables the emergence of novel strains with pandemic potential (Walff and Viet, 2021).

- **Transmission**

Influenza is a highly contagious respiratory infection transmitted primarily through respiratory droplets produced when infected individuals cough, sneeze, or talk. Transmission can also occur through contact with contaminated surfaces (fomites) followed by touching the mouth, nose, or eyes. The virus has a basic reproduction number (R_0) of approximately 1-2, meaning that an infected person will on average infect 1-2 other individuals in a susceptible population.

- **Control Strategies**

Control of influenza relies on multiple interventions. Annual vaccination is the most effective preventive measure, with vaccines updated regularly to match circulating strains. Antiviral medications, particularly neuraminidase inhibitors such as oseltamivir, can reduce illness severity and duration when administered early. Non-pharmaceutical interventions including hand hygiene, respiratory etiquette, and isolation of infected individuals help reduce transmission. The One Health approach is particularly relevant for influenza, as the virus circulates among humans, domestic animals (particularly pigs), and avian species, with the potential for both zoonotic transmission and reverse zoonosis (human-to-animal transmission) (Nypaver, *et. al.,* 2021).

- **Impact on Humans**

Seasonal influenza results in an estimated 3-5 million cases of severe illness and 290,000-650,000 deaths annually worldwide. The burden is disproportionately high in low- and middle-income countries where healthcare access is limited. Beyond mortality, influenza causes substantial morbidity, school and workplace absenteeism, and economic losses (Kyokha Ameer, 2025).

iii). Respiratory Syncytial Virus (RSV)

It is an RNA virus belonging to the Pneumoviridae family, which is classified into two major antigenic subgroups (A and B) that circulate simultaneously during epidemics. RSV is one of the most common causes of acute lower respiratory infection in infants and young children globally.

- **Transmission**

RSV is transmitted through respiratory droplets and direct contact with contaminated surfaces. The virus can survive on surfaces for several hours, facilitating transmission in healthcare settings and households. Transmission is highly seasonal in temperate climates, peaking during winter months.

- **Control Strategies**

Prevention of RSV infection has advanced significantly in recent years. Monoclonal antibodies including palivizumab and nirsevimab are available for prophylaxis in high-risk infants. RSV vaccines have recently been approved for use in older adults in the United States and Europe. Treatment remains largely supportive, though ribavirin has been used in severely immunocompromised patients (Bizot, *et. al*., 2025).

- **Impact on Humans**

It is responsible for an estimated 33.1 million cases of acute lower respiratory infection, 3.2 million hospitalizations, and nearly 59,600 deaths annually among children under five years of age. The burden is specially severe in low- and middle-income countries where access to diagnostic testing and medical care is limited. In some regions of India, RSV accounts for up to 62.5% of respiratory illness hospitalizations in young children (Asseri, 2025).

Viral Haemorrhagic Fevers

Viral haemorrhagic fevers represent a group of severe, often fatal illnesses caused by several families of RNA viruses. These diseases remain critical threats, particularly in regions with limited healthcare capacity.

i). *Ebola* and *Marburg* Viruses

Ebola and Marburg viruses belong to the Filoviridae family. These negative-sense RNA viruses cause severe haemorrhagic fever in humans and non-human primates. Multiple species of *Ebola* virus exist, with *Zaire ebolavirus* being the most virulent and responsible for the largest outbreaks.

- **Transmission**

Filoviruses are zoonotic with fruit bats suspected as the natural reservoir. Transmission to humans occurs through contact with infected animals (often through hunting or handling bush-meat). Human-to-human transmission occurs through direct contact with blood, secretions, organs, or other bodily fluids of infected individuals, as well as through contaminated surfaces and materials. Transmission is amplified in healthcare settings without adequate infection control measures.

- **Control Strategies**

Control of filovirus outbreaks relies on rapid case identification, isolation of infected individuals, contact tracing, safe burial practices, and infection prevention and control in healthcare settings. An Ebola vaccine (rVSV-ZEBOV) has demonstrated high efficacy and is now used in outbreak response. Therapeutic monoclonal antibodies have also been developed and shown to improve survival.

- **Impact on Humans**

The 2013-2016 West African Ebola outbreak was the largest in history, causing approximately 28,000 cases and 11,000 deaths. The outbreak represented how a zoonotic pathogen can spread efficiently when it reaches densely populated urban areas with poor healthcare infrastructure. Beyond mortality, Ebola outbreaks disrupt healthcare systems, reduce trust in public health institutions, and have severe economic consequences for affected communities (Rougeron*, et. al.,* 2015).

ii). Lassa fever

Lassa virus is an arenavirus endemic in West Africa, which causes Lassa fever, which ranges from mild illness to severe haemorrhagic fever with multi-organ failure.

- **Transmission**

The multimammate rat (*Mastomys natalensis*) serves as the natural reservoir for Lassa virus. Humans become infected through contact with food or household items contaminated with rodent urine or droppings. Human-to-human transmission can occur in healthcare settings through contact with infected bodily fluids.

- **Control Strategies**

Prevention focuses on rodent control and safe food storage to reduce contact with infected rodents. In healthcare settings, standard infection prevention and control measures are essential. Ribavirin, an antiviral drug, may be effective when administered early in illness. No licensed vaccine is currently available.

- **Impact on Humans**

Lassa virus is estimated to cause 100,000-300,000 infections and approximately 5,000 deaths annually in West Africa. The disease disproportionately affects rural populations with limited access to healthcare, and the true burden is likely

underestimated due to limited surveillance and diagnostic capacity (WHO, 2024).

Persistent Viral Infections: HIV and Viral Hepatitis

i). Human Immunodeficiency Virus (HIV)

HIV is a retrovirus (genus *Lentivirus*) that infects cells of the immune system, particularly CD^{4+} T lymphocytes, which exist in HIV-1 (pandemic) and HIV-2 (largely confined to West Africa). The virus originated from multiple zoonotic transmissions of simian immunodeficiency viruses from non-human primates to humans.

- **Transmission**

HIV is transmitted through sexual contact, exposure to contaminated blood or blood products, sharing of contaminated injection equipment, and from mother to child during pregnancy, childbirth, or breastfeeding.

- **Control Strategies**

Prevention combines multiple approaches like condom use, harm reduction services for people who inject drugs, antiretroviral treatment for infected individuals (which reduces transmission risk), pre-exposure prophylaxis (PrEP) for high-risk individuals, and prevention of mother-to-child transmission. Antiretroviral therapy has transformed HIV from a fatal disease to a manageable chronic condition. No curative vaccine or treatment exists, though one individual has been cured through stem cell transplantation.

- **Impact on Humans**

Since its emergence, HIV has caused an estimated 40 million deaths worldwide. The pandemic reversed decades of gains in life expectancy in the most affected regions, particularly sub-Saharan Africa. HIV infection also increases susceptibility to other infections, including tuberculosis, and is associated with increased risk of certain cancers (Orlando, *et. al.,* 2025).

ii). Viral Hepatitis (Hepatitis B and C)

Hepatitis B virus (HBV) is a DNA virus of the Hepadnaviridae family, while hepatitis C virus (HCV) is an RNA virus of the Flaviviridae family. Both cause acute and chronic hepatitis with chronic infection leading to cirrhosis and hepatocellular carcinoma.

- **Transmission**

HBV and HCV are transmitted through blood and body fluids, including sexual contact, sharing of contaminated injection equipment, transfusion of unscreened blood, and from mother to child. HBV is more efficiently transmitted sexually than HCV.

- **Control Strategies**

An effective vaccine against HBV has been available since 1982 and is recommended for universal infant immunization. No vaccine exists for HCV. Antiviral treatments can suppress HBV infection, and direct-acting antivirals can cure HCV infection in most patients. Blood donor screening has virtually eliminated transfusion-transmitted hepatitis in high-income countries.

- **Impact on Humans**

An estimated 296 million people live with chronic HBV infection and 58 million with chronic HCV infection globally. Viral hepatitis causes approximately 1 million deaths annually from cirrhosis and liver cancer. The burden is highest in low- and middle-income countries where access to prevention, diagnosis, and treatment is limited (Saraceni and Birk, 2021).

Drivers of Viral Emergence and Re-emergence

The emergence and re-emergence of viral diseases are driven by complex interactions among viral factors, human hosts, and environmental conditions.

Zoonotic Spillover Mechanisms

The transmission of a pathogen from one species to a novel susceptible species is the origin of most emerging viral diseases. Spillover events are occurring constantly, but most do not lead to sustained transmission in humans. For a pandemic to occur, a zoonotic pathogen must be able to transmit efficiently from human to human, requiring the virus to infect the appropriate tissues, evade the immune system, and be shed in sufficient quantities for onward transmission.

Viruses with broad host ranges are more likely to spill over into humans. RNA viruses are particularly prone to host switching due to their high mutation rates, which provide genetic diversity for selection to act upon when encountering new hosts (Ellwanger and Chies, 2021).

Anthropogenic Drivers

Multiple human activities increase the risk of viral emergence:

- Deforestation and land-use change bring humans into closer contact with wildlife reservoirs, increasing opportunities for spillover.
- Wildlife trade and consumption create direct pathways for pathogen transmission from animals to humans.
- Agricultural intensification, particularly industrial livestock production, creates large populations of genetically similar animals that can amplify and maintain pathogens.
- Urbanization and crowding facilitate human-to-human transmission once spillover has occurred.
- Global travel and mobility enable rapid international dissemination of novel pathogens, as demonstrated by the global spread of SARS-CoV-2 within weeks.

Climate Change

Climate change is increasingly recognized as a major driver of viral outbreaks. Rising temperatures and shifting rainfall patterns create optimal conditions for vectors such as mosquitoes, lengthen transmission seasons, and push vector-borne diseases into new geographic regions. Extreme weather events can also precipitate outbreaks by disrupting

infrastructure and bringing humans into closer contact with pathogens.

The expansion of arboviruses including dengue, chikungunya, and Zika into previously unaffected areas exemplifies the impact of climate change on disease distribution. Similarly, ecological disruptions affecting bat habitats have been linked to Hendra virus spillovers in Australia, demonstrating how climate-driven food shortages can alter reservoir host behaviour and increase pathogen shedding (Mousavi, *et. al.,* 2024).

Control Strategies and Public Health Interventions

Surveillance and Early Detection

Modern surveillance systems are essential for early detection of viral threats. Genomic surveillance, particularly whole-genome sequencing, has transformed outbreak investigation by enabling real-time tracking of transmission chains and evolutionary changes. Networks such as the COVID-19 Genomics UK Consortium demonstrated the power of genomic surveillance in rapidly identifying emerging variants.

Metagenomic next-generation sequencing extends detection capabilities by identifying any pathogen nucleic acid in a sample without requiring prior knowledge of the pathogen. This approach is particularly valuable for detecting novel or unexpected viruses.

Vaccination

Vaccination is among the most effective interventions for preventing viral diseases. The rapid development and deployment of mRNA vaccines during the COVID-19 pandemic represented a historic scientific achievement. These platforms offer advantages in speed of development and adaptability to new variants.

Established vaccination programs have dramatically reduced the burden of viral diseases. Smallpox has been eradicated through vaccination, polio is nearing eradication, and measles vaccination has prevented an estimated 23 million deaths since 2000. Influenza vaccination prevents millions of illnesses annually, though effectiveness varies by season and match with circulating strains (Shattock, *et. al.,* 2024).

Antiviral Therapies

The antiviral drugs have transformed the management of viral infections. Direct-acting antivirals can cure hepatitis C infection. Neuraminidase inhibitors reduce influenza illness severity and duration. Antiretroviral therapy has made HIV a manageable chronic condition. For COVID-19, antivirals including nirmatrelvir-ritonavir reduce the risk of severe disease and death when administered early.

Non-Pharmaceutical Interventions

The non-pharmaceutical interventions remain critical, particularly for respiratory viruses and in settings where vaccines and antivirals are unavailable. These include hand hygiene, respiratory etiquette, masking, physical distancing, improved ventilation, and isolation of infected individuals. During the COVID-19 pandemic, these measures were essential before vaccines became available and continue to supplement vaccination programs.

One Health Approach

The One Health approach recognizes that human health is connected to the health of animals and the environment. This multidisciplinary approach brings together expertise from human medicine, veterinary medicine, ecology, anthropology, and other fields to understand and prevent zoonotic spillover events.

One Health investigations have revealed critical insights into spillover mechanisms. For example, research on Hendra virus in Australia demonstrated that restoring bats' natural winter habitat could prevent spillover events by reducing nutritional stress that increases viral shedding. Such findings highlight the potential for upstream interventions that address root causes of spillover rather than responding only after human outbreaks occur (Danasekaran, 2024).

Impact on Human Health and Society

i). Morbidity and Mortality

Viral diseases remain leading causes of death and disability worldwide. Lower respiratory infections (primarily influenza, RSV, and emerging coronaviruses) are among the top causes of death globally. HIV/AIDS has caused an estimated 40 million deaths since the beginning of the pandemic. Viral hepatitis causes approximately 1 million deaths annually from cirrhosis and liver cancer.

ii). Long-Term Sequelae

Beyond acute mortality, viral infections can cause long-term health consequences. "Long COVID" affects a substantial proportion of COVID-19 survivors, with symptoms including fatigue, cognitive impairment, and respiratory issues persisting for months or years. Zika virus infection during pregnancy causes congenital abnormalities including microcephaly. West Nile virus neuroinvasive disease leads to long-term neurological sequelae in many survivors. Chronic hepatitis B and C infections progress to cirrhosis and liver cancer over decades.

iii). Economic Impact

Viral outbreaks impose substantial economic burdens through direct healthcare costs and indirect losses from reduced productivity. The economic impact of the COVID-19 pandemic has been estimated in trillions of dollars globally. Seasonal influenza causes significant economic losses through healthcare utilization and lost workforce productivity. In India, influenza is estimated to cause over 127,000 excess deaths annually with substantial associated economic costs (Faramarzi, *et. al.,* 2024).

iv). Health System Strain

Viral outbreaks can overwhelm healthcare systems, as demonstrated during the COVID-19 pandemic when hospitals in many countries reached or exceeded capacity. Even seasonal respiratory viruses strain healthcare systems during peak

periods, leading to overcrowded hospitals and increased risks of healthcare-associated infections.

v). Health Inequities

The burden of viral diseases disproportionately falls on low- and middle-income countries where access to prevention, diagnosis, and treatment is limited. Diagnostic tests for respiratory viruses remain expensive and inaccessible in many resource-limited settings. Vaccine access during the COVID-19 pandemic was highly inequitable, with high-income countries securing doses while many low-income countries struggled to access vaccines.

Future Directions and Challenges

a). Strengthening Pandemic Preparedness

The COVID-19 pandemic has highlighted the need for strengthened pandemic preparedness globally. Key priorities include strengthening surveillance systems, particularly at the human-animal interface, investing in rapid response capabilities, maintaining stockpiles of personal protective equipment and medical supplies and ensuring surge capacity in healthcare systems.

b). Addressing Diagnostic Gaps

Affordable, accurate, and accessible diagnostic tests remain urgently needed, particularly in low- and middle-income countries. Timely diagnosis is critical for patient management, infection control, and public health surveillance. Multiplex assays that can differentiate among respiratory viruses with similar clinical presentations are particularly valuable for guiding treatment and antimicrobial stewardship.

c). Ensuring Equitable Access

Ensuring equitable access to vaccines, therapeutics, and diagnostics remains a major challenge. The COVID-19 pandemic exposed global inequities in access to medical countermeasures. Strengthening local manufacturing capacity in low- and middle-income countries, technology transfer agreements, and innovative financing mechanisms are needed to address these inequities.

d). Addressing Root Causes

Preventing future pandemics requires addressing the root causes of viral emergence, including deforestation, wildlife trade, agricultural intensification, and climate change. The One Health approach provides a framework for understanding and intervening at the human-animal-environment interface. Investing in upstream prevention may be more cost-effective than responding to outbreaks after they occur.

CONCLUSION

Viral diseases causes significant threats to worldwide health security in the 21th century. The respiratory viruses consisting coronaviruses, influenza, and RSV to haemorrhagic fevers, arboviruses and persistent infections such as HIV and viral hepatitis, these pathogens can cause substantial morbidity and mortality, strain healthcare systems, and impose heavy economic losses. The majority of emerging viral diseases originate from zoonotic spillover events, driven by anthropogenic factors including agricultural intensification, deforestation, climate change, wildlife trade and urbanization.

Significant advances in genomic surveillance, diagnostic technologies, and vaccine platforms particularly mRNA vaccines have strengthened global response capacity. However, substantial gaps persist in equity, surveillance, and access to countermeasures, particularly in low- and middle-income countries. The COVID-19 pandemic has underscored the need for strengthened pandemic preparedness, affordable and accessible diagnostics, and global cooperation in ensuring equitable access to medical countermeasures.

Preventing future pandemics requires addressing the root causes of viral emergence through a One Health approach that integrates human, animal, and environmental health. Understanding the complex interplay between viral pathogens, human hosts, and environmental factors is essential for developing effective prevention strategies and strengthening global health security against future viral threats.

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