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EMERGING ZOONOTIC DISEASES: ECONOMIC IMPORTANCE, PREVENTION AND CONTROL

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ABSTRACT
Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and man. It is believed that mounting anthropogenic activity during these recent decades, such as land-use change and human population growth, has led to increased interactions between humans and wild vertebrates, resulting in an increased risk of disease spillover to human populations. The one health concept plays a significant role to address emerging and re-emerging zoonoses; to control the effect of zoonotic diseases among humans, animals, and environmental components; and to make the world free from threats of zoonotic diseases. Because of the strong interrelatedness among animals, humans, and environment; research focusing on the one health approach need to be prioritized to identify critical intervention steps in the transmission of pathogens. Robust active surveillance targeting all components of the one health approach needs to be implemented to enable early and accurate detection of zoonoses, so that effective control measures could be taken. This review provides information about zoonoses, emerging and re-emerging zoonoses, prevention and control of zoonoses with emphasis on One Heath approach.

Keywords: Zoonosis, Disease, Emerging, Pathogens

INTRODUCTION

The term "Zoonosis" (zoonoses, plural) is derived from the Greek word "Zoon", which means animal, and "nosos", which means illness, was coined at the end of the nineteenth century by Rudolph Virchow to designate human diseases caused by animals (Chomel, 2009). The term 'zoonosis' is also considered to be shorter and more convenient than 'anthropozoonosis' (animals to humans) and 'zooanthroponosis' (humans to animals), which are based on the prevailing direction of transmission between humans and other vertebrates. The World Health Organization (WHO) defines zoonosis as any disease or infection that is naturally transmissible from vertebrate animals to humans or from humans to animals (WHO, 2020). They are therefore diseases and infections that are naturally transmitted between vertebrate animals and man.

Zoonoses is a great public health concern and a direct human health hazard that may even lead to death (Grace *et al*., 2012). While humans have coexisted with wild animals for millennia, it is believed that mounting anthropogenic activity during these recent decades, such as land-use change and human population growth, has led to increased interactions between humans and wild vertebrates, resulting in an increased risk of disease spillover to human populations (Plowright *et al*. 2021; Gagne *et al*. 2022). The greatest risk for zoonotic disease' transmission occurs at the human-animal interface through direct or indirect human exposure to animals, livestock products such as meat, milk, eggs and derived processed products and/or their environments, including natural, cultivated, built (abattoirs) and commercial environments (wet markets).

As our world grows progressively interdependent and the populations of people, domestic animals, wildlife, and animal products also increase and expand globally, we can expect more interactions among these groups and certainly the era of emerging and reemerging zoonoses will also expand and grow proportionately (Tomley and Shirley, 2009). As the human–animal interfaces intensify and accelerate, there is a growing concern with the emergence and reemergence of more zoonoses and animal-associated diseases, including leptospirosis, leishmaniasis, Q fever, toxoplasmosis, anaplasmosis, food-borne trematodes, ehrlichia, bartonella, Chagas disease, and toxocariasis. Although most of these diseases can be considered in the category of neglected diseases and are increasingly associated with slums and periurban locations, some of these diseases are also found in developed countries because of the relocation of human populations, global travel, and the movement of food and animal products as part of the rapidly expanding global food system.

MATERIALS AND METHODS

Classification of Zoonoses

Based on etiology, zoonoses are classified into bacterial zoonoses (such as anthrax, salmonellosis, tuberculosis, Lyme disease, brucellosis, and plague), viral zoonoses (such as rabies, acquired immune deficiency syndrome- AIDS, Ebola, and avian influenza), parasitic zoonoses (such as trichinosis, toxoplasmosis, trematodosis, giardiasis, malaria, and echinococcosis), fungal zoonoses (such as ring worm), rickettsial zoonoses (Q-fever), chlamydial zoonoses (psittacosis), mycoplasma zoonoses (*Mycoplasma pneumoniae* infection), protozoal zoonoses, and diseases caused by acellular non-viral pathogenic agents (such as transmissible spongiform encephalopathies and mad cow disease) (Chomel, 2009; Rahman, 2020).

Other classifications of zoonoses may include a classification based on the categories of people at risk or relating to the type of human activity, such as occupational zoonoses (which occur when people are infected during their professional activity; such as brucellosis in farmers, veterinarians, or slaughterhouse employees, Lyme disease in foresters, rabies in wildlife trappers or taxidermists), zoonoses associated with recreational activities (plague, hantavirus infection, Lyme disease, tularemia, or parasitic larva migrans), domestic zoonoses (diseases acquired from pets), or accidental zoonoses (some very rare and peculiar circumstances of infection, as well as foodborne outbreaks) (Chomel, 2009)..

Another aspect of zoonoses classification concerns their clinical manifestations and their diagnosis. Clinical diagnosis of zoonoses is not always easy, especially if the symptoms are different in animals and humans, or if clinical signs are present only in humans. If clinical signs are observed in animals and humans, zoonoses are designated as phanerozoonoses. If symptoms are similar in both animals and humans, they are considered isosymptomatic (rabies and tuberculosis), whereas they are anisosymptomatic if the symptoms are different in humans and animals (anthrax, brucellosis, psittacosis, and Rift Valley fever). In some instances, subclinical infection is observed in animals and clinical illness in humans, or vice versa. In such cases, these zoonoses are designated as cryptozoonoses (Chomel, 2009).

When considering alternatives for control measures, it is the primary epidemiological classification based on the zoonosis maintenance cycle that is of major importance. This classification divides the zoonoses into four categories.

1. Direct zoonoses (orthozoonoses) are transmitted from an infected to a susceptible vertebrate host by direct contact, by contact with a fomite, or by a mechanical vector. Direct zoonoses may be perpetuated in nature by a single vertebrate species, such as dogs or foxes for rabies or cattle, small ruminants or swine for brucellosis.
2. Cyclozoonoses require more than one vertebrate species, but no invertebrate host, in order to complete the developmental cycle of the agent. Cyclozoonoses include human taeniases or pentastomid infections. Most of the comparatively few cyclozoonoses are cestodiases.
3. Pherozoonoses (also called metazoonoses) are zoonoses that require both vertebrates and invertebrates for the completion of their infectious cycle.

In pherozoonoses, the infectious agent multiplies (propagative or cyclopropagative transmission) or merely develops (developmental transmission) in the invertebrate; there is always an extrinsic incubation period in the invertebrate host before transmission to a vertebrate host. Pherozoonoses include arbovirus infections, plague, Lyme borreliosis, or rickettsial infections.

4. Saprozoonoses have both a vertebrate host and an inanimate developmental site or reservoir. The developmental reservoir is considered nonanimal, such as organic matter, including food, soil, and plants. In this group of zoonoses, direct infection is usually rare or absent. Saprozoonoses include histoplasmosis, *Erysipelothrix* infection, or listeriosis (Chomel, 2009).

Emerging and Re-Emerging Zoonoses

Emerging zoonoses are zoonotic diseases caused either by apparently new agents or by previously known microorganisms, appearing in places or in species in which the disease was previously unknown. New animal diseases with an unknown host spectrum are also included in this definition. Natural animal reservoirs represent a more frequent source of new agents of human disease than the sudden appearance of a completely new agent (Meslin, 1992). Therefore, while emerging zoonoses are new or re-spreading diseases, reemerging zoonoses are diseases that have returned after a decline.

Emerging and re-emerging diseases have significant impacts, not only on public health, but also on socio-economic issues around the globe (Bao *et al*., 2017). Among 175 reported emerging diseases, 132 diseases are considered to be emerging zoonotic diseases. Another report estimated that about 60.3% of the emerging diseases can be categorized under zoonoses. Among them, 71.8% originated from wildlife (Jones *et al*., 2008; Rahman *et al*., 2020).

Factors explaining the emergence of a zoonotic or potentially zoonotic disease are usually complex, involving mechanisms at the molecular level, such as genetic drift and shift, and modification of the immunological status of individuals and populations. Social and ecological conditions influencing population growth and movement, food habits, the environment and many other factors may play a more important role than changes at the molecular level. Bacterial enteric diseases due to *Salmonella enteritidis* and *Escherichia coli* O157:H7 are examples of diseases associated with changing farming practices, trade and consumer habits (Meslin, 1992).

The spectrum of infectious diseases is changing rapidly in conjunction with dramatic societal and environmental changes. Exponential human population growth with expanding poverty and urban migration is occurring worldwide, international travel and trade is increasing. Exponential human population growth with expanding poverty and urban migration is occurring worldwide, international travel and trade is increasing, and technology is rapidly changing – all of which affect the risk of exposure to infectious agents. Disease emergence often follows ecological changes caused by human activities such as agriculture or agricultural change, migration, urbanization, deforestation, or dam building. Of these new diseases, surprisingly, most of the emergent viruses and many of the emergent bacteria are zoonotic (Baker *et al*., 2022).

Major emerging zoonoses include avian influenza, bovine spongiform encephalopathy (BSE), feline cowpox, rotavirus infection, norovirus infection, ebola virus diseaese, hantavirus infection, west nile fever, canine leptospirosis, MRSA infection, cat scratch disease, severe fever with thrombocytopenia syndrome (SFTS), middle east respiratory syndrome (MERS), severe acute respiratory syndrome (SARS), and the most recent coronavirus disease 2019 (COVID-19) (Wang *et al*., 2020). On the other hand, rabies, brucellosis, Japanese encephalitis, tuberculosis (*M. bovis*), and *Schistosoma japonicum* infection are considered to be re-emerging zoonoses in many parts of the world (Rahman *et al*., 2020).

RESULTS AND DISCUSSION

Zoonotic Transmission

Zoonotic transmission may be direct such as with rabies or indirect through either vectors such as ticks, mosquitoes or other insects (trypanosomiasis) or through food, water, or soil (helminths) (King, 2011). Zoonotic transmission involves the interaction of a pathogen and at least two host species: (a) a natural reservoir, infected with the pathogen and often asymptomatic (shedding the pathogen), (b) a recipient host, presenting the disease (infected with the pathogen from a different host), and (c) an intermediate host, that may or may not be present, acting as a bridge or mixing vessel (vertebrate or invertebrate vector). Pathogens can be transmitted to the recipient host (humans) directly from the natural reservoir, from the intermediate vertebrate or invertebrate host, or from the environment, resulting in transmission to humans without spread ("dead-end spillover"), or in adaptation for human-to-human transmission (Ellwanger and Chies, 2020). Although these events are relatively rare, in the last century, outbreaks of emerging and re-emerging viral zoonoses have increased in frequency and magnitude with significant human and animal health impacts, as well as incalculable and far-reaching economic consequences, as a result of the intensification of the animal-human interface, driven primarily by anthropogenic factors (Baker *et al*., 2022). Table 1 lists some

major zoonotic diseases with their etiological agents and animal host.

Table 1: Major Zoonotic Diseases, Their Etiological Agents and Hosts

Disease	Etiology	Animal Host
Bubonic plague	*Yersinia pestis*	Rock squirrels, wood rats, mice,rabbits, ground squirrels, chipmunks
Leprosy	*Mycobacterium leprae*	Monkeys, rats, mice, and cats
Tularemia	*Francisella tularensis*	Rabbits, squirrels, muskrats, deer, sheep, bull snakes, wild rodents, beavers, cats, and dogs
Bordetellosis	*Bordetella bronchiseptica*	Cats and dogs
Enterohemorrhagic *Escherichia coli* infections	*E coli* O157:H7	Cattle, sheep, pigs, deer, dogs, and poultry
Salmonellosis	*Salmonella enterica, Salmonella bongor*	Domestic animals, birds, and dogs
Rabies	Rabies virus, Genus—*Lyssavirus* Family—*Rhabdoviridae*	Cattle, horses, cats, dogs, bats, monkeys, wolves, skunks, rabbits, and coyotes
Newcastle disease	Paramyxovirus,	Poultry and wild birds
Avian influenza	Influenza A virus	Ducks, chickens, turkeys, dogs, cats, pigs, whales, horses, seals, and wild birds
Dengue fever	Dengue virus	Monkeys and dogs
Zika fever	Zika virus	Apes and monkeys
Rift Valley fever	Rift Valley fever virus	Buffaloes, camels, cattle, goats, and sheep
Ebola virus disease (Ebola Hemorrhagic Fever)	Ebola virus Genus—*Ebolavirus* Family—*Flaviviridae*	Monkeys, gorillas, chimpanzees, apes, and wild antelopes
Marburg viral hemorrhagic fever	Marburg virus	Fruit bats and monkeys
Chikungunya fever	Chikungunya virus	Monkeys, birds, and rodents
Zika fever	Zika virus	Apes and monkeys
Severe acute respiratory syndrome (SARS)	SARS coronavirus (SARS-CoV)	Bats, dogs, cats, ferrets, minks, tigers, and lions
Trichinellosis	*Trichinella* spp.	Pigs, dogs, cats, rats, and other wild species
Cryptosporidiosis	*Cryptosporidium parvum*	Cattle, sheep, pigs, goats, horses, and deer
Coccidioidomycosis	*Coccidioides immitis, Coccidioides posadasii*	Dogs, horses, pigs, and ruminants
Toxocariasis	*Toxocara canis, Toxocara cati*	Dogs and cats
Toxoplasmosis	*Toxoplasma gondii*	Pigs, sheep, goats, poultry, and rabbits
Psittacosis	*Chlamydia psittaci*	Parrots, parakeets, lories, cockatoos, cattle, sheep, and goats
Mad Cow Disease, also known as BSE (Bovine spongiform encephalopathy). In human known as Creutzfeldt–Jakob disease (CJD)	Prion protein	Cattle, sheep, goats, mink, deer, and elks
Tinea/ringworm infection	*Microsporum* spp., *Trichophyton* spp.	All animals like cattle, sheep, goats, cats, and dogs
Aspergillosis	*Aspergillus* spp.	All domestic animals and birds
Lyme disease	*Borrelia burgdorferi*	Cats, dogs, and horses
Bordetellosis	*Bordetella bronchiseptica*	Cats and dogs

Source: (Rahman, 2020)

Medical and Economic Importance of Zoonoses

Zoonoses are important to Public Health because of their number, their frequency, and their severity in relation to human health. There are more than 250 zoonoses according to the WHO Zoonoses Expert Committee. There are very few vertebrates that are not involved with one or more zoonoses. Human infection most often occurs when infection persists in animals, such as rabies, brucellosis, or tuberculosis. Zoonoses frequency varies for each disease and depends on the geographical distribution of reservoirs, agents, and population density, as well as efficiency of controlled measures. Some zoonoses are ubiquitous, such as salmonellosis and leptospirosis. (Chomel, 2009).

Zoonoses are a tremendous economic burden to humans due to the loss of diseased animals and agricultural production, cost of prevention, and treatment, debilitation of and productivity losses to humans. It is quite difficult to evaluate such costs precisely, but some estimates have been published that illustrate the economic impact of zoonotic diseases. Economic losses resulting from foodborne parasitic zoonoses

are difficult to assess, as underlined by Murrell. In Mexico, porcine cysticercosis was reported to be responsible for a loss of more than one-half of the national investment in swine production and for more than $17 million annually in hospitalization and treatment costs for humans with neurocysticercosis. In Africa, losses of $1–2 billion per year due to bovine cysticercosis have been reported (Chomel, 2009).

Neglected Zoonoses

A neglected zoonotic disease (NZD) is a zoonosis that is commonly associated with poverty and impacts the lives and livelihoods of millions of poor livestock keepers or those living in periurban slums primarily in developing countries. Neglected zoonotic diseases are a subset of the neglected tropical diseases. The term "neglected" highlights that the diseases affect mainly poor and marginalized populations in low-resource settings (WHO, 2015). Some NZDs are part of existing lists of neglected tropical diseases (NTDs) or comprise their own list but all share similar characteristics and attributes (King, 2011).

A key characteristic of NZDs is that they are closely associated with poverty and they disproportionately affect neglected populations. Poor people are more at risk of contracting many zoonoses. Anthrax, bovine tuberculosis, and brucellosis are primarily occupational diseases, and small livestock producers worldwide are at risk and more frequently acquire these infections from their animals (King, 2011).

The poor are also more vulnerable to diseases associated with consumption of livestock products and are at risk for zoonotic diseases such as cysticercosis and other parasitic and food-borne illnesses. In addition, vectors, water, and the environment can also be sources of NZDs. Once infected, it is the poor that are least likely to get proper medical care. The impact of NZDs is also worse in poor households where a dual burden is borne because both people and their animals are involved. Thus, NZDs not only make members of families ill, but also at the same time, limit the productivity of their livestock and poultry and, thus, take away the funds that would be used for emergencies, their family's well-being, and funds used to cope with these illnesses (King, 2011).

As the human–animal interfaces intensify and accelerate, there is a growing concern with the emergence and reemergence of more zoonoses and animal-associated diseases, including leptospirosis, leishmaniasis, Q fever, toxoplasmosis, anaplasmosis, food-borne trematodes, ehrlichia, bartonella, Chagas disease, and toxocariasis. Although most of these diseases can be considered in the category of neglected diseases and are increasingly associated with slums and periurban locations, some of these diseases are also found in developed countries because of the relocation of human populations, global travel, and the movement of food and animal products as part of the rapidly expanding global food system (King, 2011).

Many zoonotic diseases are endemic in the developing world, which negatively impacts the health conditions and livelihoods of poor people. Because of their endemic nature, they tend to be under-reported and have been largely neglected by many funding agencies compared to emerging and re-emerging zoonoses and thus have been named as neglected zoonoses (Maudlin *et al*., 2009). Most developed countries have been successful in the control and elimination of neglected zoonotic diseases (WHO, 2011).

Mainly, tropical countries are more vulnerable for neglected diseases, which is why these diseases have been sometimes known as neglected tropical diseases. Since the neglected zoonotic diseases have lower priority in the health systems in many countries, they have silently triggered significant morbidity among rural people. The basic features of neglected zoonotic diseases are shown in Figure 1.

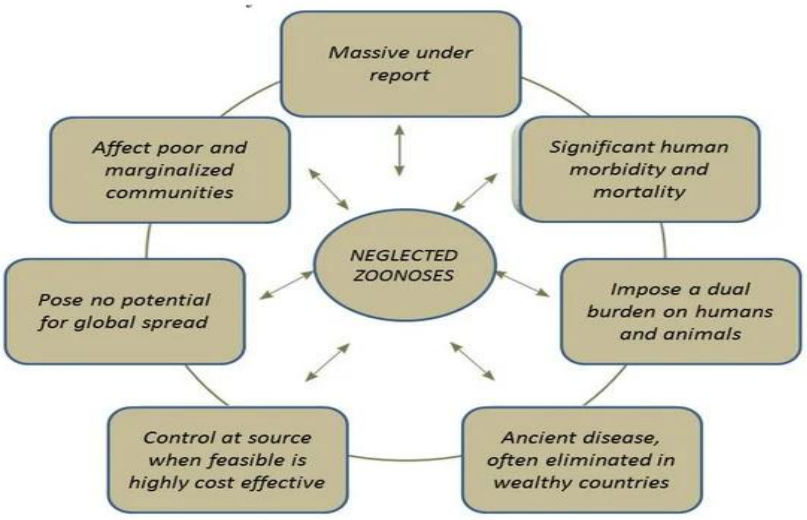

Figure 1: Basic Features of Neglected Zoonotic Diseases (Rahman *et al*., 2020)

Challenges of Managing Zoonotic Infections

According to the world health organization (WHO, 2025), the challenges of managing zoonotic infections can be summarized as follows:

Organizational

(i) Poor level of awareness among policy and decision-makers about the serious nature of zoonotic diseases; (ii) Insufficient information on the burden , trend and risks of zoonotic diseases; (iii) Inadequate resources and skilled manpower for control of zoonotic diseases; (iv) Presence of other competitive health priorities often taking precedence; (v) Lack of transparency of the countries to report emergence or occurrence of zoonotic disease for fear of repercussions; (vi) Weakness or absence of collaboration and cooperation between the public health, veterinary, agriculture and wildlife sectors; (vii) Inadequate collaboration and partnerships to harness resources to support the prevention and control programme of zoonotic diseases (viii) Absence of cross-talk within the health sector between the surveillance, clinical

services and laboratory services departments. (ix) Breakdown or weakness of health infrastructures especially in countries with complex emergencies;

Diagnosis and Detection

(i) Lack of integration of human and veterinary sector for exchange of epidemiological and laboratory surveillance data of the human and health sectors; (ii) Weak disease surveillance system and inadequate diagnostic capacities to detect zoonotic infections; (iii) Difficulties in international transfer of samples for logistic and economic reasons. (iv) Difficulties in conducting field investigation in remote areas where most of the emerging zoonotic outbreaks occur. (v) Weak cross-border collaboration, surveillance and information exchange between the countries (vi) Inadequate community engagement in the zoonotic control programme

Control and Interruption of Transmission

(i) Insufficient capacities of countries to plan, mobilize and implement appropriate control measures. (ii) High probability of nosocomial transmission of some of the newly emerging zoonoses in health-care settings; (iii) Poor application of strict barrier nursing and other appropriate infection control measures in health-care facilities. (iv) Lack of information on high-risk behaviours, including cultural and social factors that are associated with risk of transmission of emerging zoonoses in the community; (v) Inappropriate or inadequate vector control operations. (vi) Lack or insufficient evidence on some of the public health control measures.

Antimicrobial resistance is a complicating factor in the control and prevention of zoonoses. The use of antibiotics in animals raised for food is widespread and increases the potential for drug-resistant strains of zoonotic pathogens capable of spreading quickly in animal and human (WHO, 2020).

Prevention and Control of Zoonoses

The unpredictable emergence of zoonoses, their potential to cause severe diseases in humans and animals, and the frequent absence of effective vaccines and antiviral treatments, make their containment difficult. Therefore, the ability to predict and prevent future outbreaks depends on recognizing, understanding, and mitigating this complex and multifactorial process, which involves the interaction of animals, environment, pathogens, and humans, creating a favorable environment for interspecies transmission. However, to effectively achieve these actions, collaboration and transdisciplinary partnerships are required (Villarroel *et al*., 2023).

Prevention methods for zoonotic diseases differ for each pathogen; however, several practices are recognized as effective in reducing risk at the community and personal levels. Safe and appropriate guidelines for animal care in the agricultural sector help to reduce the potential for foodborne zoonotic disease outbreaks through foods such as meat, eggs, dairy or even some vegetables. Standards for clean drinking water and waste removal, as well as protections for surface water in the natural environment, are also important and effective. Education campaigns to promote handwashing after contact with animals and other behavioural adjustments can reduce community spread of zoonotic diseases when they occur (WHO, 2020).

One Health Approach for Zoonoses Control

One Health is defined as the collaborative effort of multiple disciplines, working locally, nationally, and globally, to attain optimal health for people, animals, and the environment (AVMA One Health Task Force, 2009). It is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent. The one health concept encourages collaborations among wildlife biologists, veterinarians, physicians, agriculturists, ecologists, microbiologists, epidemiologists, and biomedical engineers to ensure favorable health for animals, humans, and our environment (One Health, 2020).

The premise for strategic framework for control of zoonotic infections should lie on the concept of "One Health" approach which is a common coordination mechanism, joint planning, joint implementation, community participation, capacity building and joint monitoring and evaluation framework between the animal health and human health sector. According to Pieracci *et al*., (2016). the recommendations provided by one health approach to prevent and control zoonoses are: (1) developing "Zoonotic Disease Unit" for betterment of the human and animal health agencies; (2) developing national strategy for "Zoonotic Disease Unit"; (3) engaging leadership among multi-sectoral researchers and relevant personnel to prioritize zoonotic disease research; (4) adopting veterinary public health policies with collaborators from other countries; and (5) reviewing the zoonotic diseases on a regular basis (2–5 years) to address the emerging and re-emerging diseases through regular surveillance, epidemiological implementations, and laboratory diagnosis.

In brief, the one health concept plays a significant role to address emerging and re-emerging zoonoses; to control the effect of zoonotic diseases among humans, animals, and environmental components; and to make the world free from threats of zoonotic diseases.

CONCLUSION

Many human infectious diseases seem to originate from animals. These pathogens cause diseases in animals and also pose a serious threat to humans. The majority of the human infectious diseases have animal origins. These pathogens do not only cause diseases in animals, but they also pose a serious threat for human health. Altered food habit, climate change, and environmentally unfriendly human operations have in many cases influence the emergence and reemergence of many zoonotic diseases because of the increased contact between humans and wild animals. The recent COVID-19 pandemic exemplifies the devastating impact of zoonosis on the human population. Because of the strong interrelatedness among animals, humans, and environment; research focusing on the one health approach need to be prioritized to identify critical intervention steps in the transmission of pathogens. Robust active surveillance targeting all components of the one health approach needs to be implemented to enable early and accurate detection of zoonoses, so that effective control measures could be taken.

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