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Research Article

Emerging Zoonotic Diseases and Strategies for Their Management

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A B S T R A C T

As per the World Health Organization (WHO), any disease or infection that is naturally transmissible from vertebrate animals to humans or from humans to animals is classified as a zoonosis and these diseases can cause many different types of illnesses in people and animals, ranging from mild to serious illness and even death. Due to the strong interrelatedness among animals, humans, and the environment; research on zoonotic diseases, their management and strategies for prevention focusing on the one health approach need to be prioritised to identify critical intervention steps in the transmission of pathogens. Active surveillance targeting all components of the one health approach needs to be implemented to early and accurately detect zoonoses, and timely human immunization and pathogen/ vector control measures could be organised. These measures are focused on robust disease surveillance, community awareness and community engagement.

Keywords: Zoonoses, Vector, Transmission, Pandemic

Background

Humans, animals, and the environment play a significant role in the emergence and transmission of different infectious diseases. Most of the infectious diseases affecting humans are of animal origin. The "Asia Pacific Strategy for Emerging Diseases: 2010" report estimated that around 60% of emerging human infections are zoonotic in nature and among these pathogens, more than 70% originated from wildlife species (Agyopong et al., 1975). According to the World Health Organization (WHO), any disease or infection that is naturally transmissible from vertebrate animals to humans or from humans to animals is classified as zoonosis (Ajala, 2013). Zoonoses are a great public health concern and a direct human health hazard that may even lead to death. Due to climate change, human travel and other reasons, vector-borne diseases are on the rise in many countries and re-emerging in others. At the same time, new vector species are also detected. Consequently, many countries and institutions that had previously controlled or eradicated some of those diseases witnessed a resurgence and rise in numbers impacting human and animal health as well as their economies denting their limited public health budget for vector population suppression and disease control. Regardless of the reasons, the situation will continue to deteriorate if no significant action is undertaken. To that effect, vector control programs are now being established in newer areas and revitalised where one existed. However, the criteria for developing, implementing,

and evaluating vector population suppression programmes are activated without clear, measurable objectives and they are also not based on sound vector or disease surveillance. Further, standardized guidelines for the use of insecticides were also not readily available/ provided. Hence, a need exists to examine the essential elements required for a comprehensive vector control programme, which provides program managers with a detailed and comprehensive look and helps identify strengths, weaknesses, opportunities, and threats (SWOT) for appropriate attention and also to incorporate those items in capacity enhancement programs.

Economic Losses due to Zoonoses

Human and animal deaths caused by zoonotic diseases can impose massive economic losses on any country. Even if animals do not die, animal health and productivity can still be negatively impacted. This can lead to a significant loss of animal products such as meat, milk, and eggs, which can be more than 70%. Factory closures lead to a contraction in the macroeconomic supply of goods and services (Maital and Barzani, 2020).

Zoonotic Impact on Human Health and Nutrition

These are greatly affected due to the reduced supply of high-protein food of animal origin such as milk, meat, and eggs. Zoonotic diseases, such as brucellosis and toxoplasmosis, can lead to infertility, abortion, and weak offspring. This can cause great economic losses to farmers and to the whole country. The global economy was severely impacted by the SARS outbreak, which affected multiple sectors including the tourism sector. The emergence of the highly pathogenic avian influenza in recent times also significantly curtailed tourism and resulted in severe economic losses to the country (Budke et al., 2011). As per one recent survey, the impact on demand slows down the growth of the global economy – between 1.8-2.2% instead of the 2.5% growth envisioned at the start of the year (Maital and Barzani, 2020).

Impact on Travel/ Tourism

The travel industry is poised to lose significant revenue due to the pandemic. Earlier also, India faced economic losses due to the restriction of tourism that resulted from the 1994 plague outbreak. COVID-19 has significantly impacted all sectors of society including the sports sector (Mavroide, 2008). It is estimated that millions of people were subjected to extreme poverty due to the stalled growth resulting from this pandemic.

Impact on Day-to-Day Life

The movement restrictions imposed in many countries including India made the human populations struggle for their daily activities including employment potential. The closure of industries added fuel to the fire.

Emerging and Re-emerging Zoonoses

Emerging zoonosis is a zoonosis that is newly recognised, newly evolved, or has occurred previously but shows an increase in incidence or expansion in geographical, host or vector range (Sunil et al 2020). At least 250 zoonoses were listed as emerging and re-emerging zoonotic diseases during the last 70 years. These diseases have been spread rapidly throughout the world with increasing incidence along with geographical range. Humans are affected due to close contact with animals which act as reservoirs for emerging and re-emerging zoonotic diseases. Increased human-animal contact or interaction resulting from changes in human and animal behaviour, habitat, ecology, vector biology, pathogen adaptability, change in farm practices, livestock production systems, food safety, urbanisation, deforestation, and climate change are among the triggering factors for the emergence of zoonotic diseases. Wildlife can act as a source or a reservoir for emerging and remerging zoonotic disease pathogens. Emerging and re-emerging diseases have significant impacts, not only on public health but also on socio-economic issues around the globe. Among 175 reported emerging diseases, 132 diseases are considered to be emerging zoonotic diseases (Ayi et al 2010). Another report estimated that about 60.3% of the emerging diseases can be categorised under zoonoses. Among them, 71.8% originated from wildlife (Sunil et al 2020).

Major emerging zoonoses include avian influenza, rotavirus infection, norovirus infection, Ebola, hantavirus infection, West Nile fever, canine leptospirosis, MRSA infection, Middle East respiratory syndrome (MERS), Severe acute respiratory syndrome, and the most recent SARS COV-19 virus. The re-emerging infections are rabies, brucellosis, Japanese encephalitis, tuberculosis (M. *bovis*), H5N1 virus and *Schistosoma japonica* infections in many parts of the world.

Types of Zoonoses Based on Aetiology

Across the globe, the 13 most common zoonoses were most impactful on poor livestock workers in low- and middle-income countries and have caused an estimated 2.4 billion cases of illness and 2.7 million deaths in humans per year in addition to their negative effect on human health (Deressa *et al*., 2008) and also affect animal health. Based on aetiology, zoonoses are classified into (i) Bacterial zoonoses viz., Tularaemia, anthrax, salmonellosis, tuberculosis, Helicobacter infection, Lyme disease, brucellosis, plague and e coli infections, (ii) Viral zoonoses viz., avian influenza, Zika fever, rabies, acquired immune deficiency syndrome-AIDS, Ebola, chikungunya, avian influenza, Mpox, Hanta viral fever, West Nile virus, (iii) Parasitic zoonoses viz., trichinosis, toxoplasmosis, trematodosis, giardiasis, malaria, and echinococcosis, (iv) Rickettsial zoonoses viz., Q-fever,

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(v) Chlamydial zoonoses viz., psittacosis, (vi) Mycoplasmal zoonoses viz., Mycoplasma pneumoniae infection), (vii) Protozoal zoonoses, and (viii) diseases caused by acellular non-viral pathogenic agents (Ayi et al., 2010).

Zoonoses Based on Transmission

Direct Zoonoses

Pathogens can be transmitted to humans directly or indirectly from animals. Diseases that are transmitted directly to humans from animals through media such as air are known as direct zoonoses (Opiu et al., 2007). Avian influenza is a direct zoonosis, which spreads from animals to humans through droplets. Infected animals can also directly transfer pathogens to susceptible humans by bites such as in the case of rabies, which is one of the deadliest zoonotic diseases.

Vector-borne Zoonoses

Similarly, pathogens can be transmitted to humans via vectors (carrier animals). Arthropods like mosquitoes and ticks are often considered to be the only vectors; however, any animal that has the potential to transmit pathogens to humans can be considered a vector (Das, 1991). Zoonoses in which both vertebrate and invertebrate hosts are involved are known as meta-zoonoses such as with arbovirus infection. Most zoonotic diseases are transmitted to humans from animals and vice versa (reverse zoonoses). Examples of such pathogens include *Campylobacter* spp., *Salmonella enterica* Serovar *Typhimurium, influenza A* virus, *Cryptosporidium parvum*, *Ascaris lumbricoides*, and *Giardia duodenalis*. About 60% of human infectious diseases come from vertebrate animals (Alilio et al 1998 and Deressa et al 2005). Middle East Respiratory Syndrome (MERS), which is transmitted to humans from camels, is an emerging viral zoonotic disease. MERS first emerged in Saudi Arabia in 2012 and the disease is caused by a coronavirus known as the MERS coronavirus (MERS-CoV). MERS infections can cause significant mortality rates and deleterious public health impacts (Sunil et al., 2020). The human fatality rate from MERS is around 30–35%. 4000 birds (both ducks and chicks) are being culled in the Bokaro district of Jharkhand State currently.

Domestic Zoonoses

Direct human contact with animals has expanded with the introduction of domestication of different vertebrate animals (WHO 1986). Cattle, sheep, goats, dogs, cats, horses, pigs, and other domestic animals act as reservoirs of pathogens of domestic zoonoses and can transmit diseases to humans (Kaneko, 2010). Pathogens can be transmitted through direct contact or animal-origin foods. Examples are brucellosis, anthrax, rabies, tuberculosis, campylobacteriosis, leptospirosis, toxoplasmosis, ancylostomiasis, toxocariasis, listeriosis, bovine pustular stomatitis, rotavirus infection, and Q fever (Barnes, 2000, Kaneko, 2010). Brucellosis is one among such bacterial zoonotic diseases causing influenza-like infections, pneumonia, and other complications including meningitis, endocarditis, septicemia, serious weakness, pain in muscles and joints, extreme headache, fever, and night sweats infecting 500,000 human beings throughout the world every year (Whittaker, 2014), especially among dairy farm workers, caretakers, abattoir workers, veterinarians, and village inhabitants and is classified as a forgotten neglected zoonosis as per the WHO. The common transmission pattern of brucellosis to humans occurs through the consumption of unpasteurised milk or milk products. In humans, it causes.

In many houses nowadays, pets of exotic species are kept along with common pets and about 14–62% of pet owners allow their pets in their bedrooms. Many types of zoonoses such as salmonellosis, staphylococcosis, and rabies are found in a wide range of pets and companion animals. Nowadays, birds like canaries, finches, sparrows, parrots, parakeets, and budgerigars are very common in developed and developing countries. Therefore, many people are at risk of acquiring new zoonotic diseases from pets, companion animals, and exotic birds and animals (Sunil et al., 2020). Like pet animals, these birds are also potential transmitters of zoonotic diseases like *Coxiella burnetii*, *Coxiella psittaci*, Salmonella spp., Listeria monocytogenes, Mycobacterium spp., and Lyme disease. Many of these pathogens are potentially enough to cause serious diseases in humans such as salmonellosis, chlamydiosis, and avian influenza - H5N1. The transmission can take place at home, outside, pet shops, hospitals, or other places.

Fish-associated zoonotic pathogens are mainly bacteria (65). *Erysipelothrix rhusiopathiae* is a fish-borne pathogen that causes systemic skin diseases in marine mammals [78]. Often, fish unsusceptible to these infections are capable of causing serious sickness in humans. However, these opportunistic fish-borne bacterial infections are limited. These zoonotic infections mostly are transmitted to humans through the non-hygienic handling of aquatic animals and/or their products.

Zoonoses from Food-borne Pathogens

Food acts as an important medium to transmit pathogens—known as food-borne pathogens. Mortality, which impacts millions, is often associated with diarrheal diseases caused by contaminated food and drinking water (Tomori and Oluvayelu, 2023). An estimate indicated that 1 in 10 persons around the world annually consume contaminated food and water impacting about 420,000 people including 125,000 children die. Common food-borne zoonotic pathogens include Salmonella enterica serovar Enteritidis and Campylobacter spp. (90%) and Shiga toxin-producing Escherichia coli (STEC), and Hepatitis E virus. All domestic

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livestock, including poultry, can act as a reservoir for bacteria causing food-borne illness (Tomori and Oluvayelu, 2023). Many edible insects pose health risks to humans by causing allergies and other disease conditions (Marchi et al, 2021].

Zoonoses Transmission Through Reservoirs

Wild animals such as mammals, reptiles, birds, fish, and amphibians act as a reservoir of zoonotic pathogens with the potential of transmission to humans or other animal hosts. The involvement of wild animals in the epidemiology and transmission of zoonotic diseases is alarming. The emergence and re-emergence of these pathogens is dependent on their transmission patterns among wild and domestic animals, and humans. In emerging and re-emerging diseases, there is significant transmission of pathogens to humans from wild animals. Human infections are usually developed from wild animals via direct contact or vector-mediated sources (such as in the case of rabies and/ or lyssaviruses, hantaviruses, Nipah virus, West Nile virus, and causative agents of leptospirosis and ehrlichiosis). The spread of infections largely depends on human-human transmission such as with HIV, Ebola virus, and coronaviruses [148]. It is quite interesting that bats of around 1000 species naturally distributed all over the world are natural reservoirs for about 80 human viral diseases. Their success is due to their flying nature and role in insect control, reseeding of cut forests and pollination of plants. Their high density and gregarious roosting behaviour enhanced the intra and inter-species transmission of infections. Added to this, the migratory habit makes great dispersal capacity of pathogens. Pathogens can be directly transmitted by these bats by direct contact with infected bats.

Control of Zoonoses

Zoonoses present a serious health threat to the international community. About 58–61% of human diseases are communicable and up to 75% are zoonotic (transmitted from animals) [226,227]. Zoonosis involves the interaction of humans, animals, and the environment, and therefore a multi-sectorial approach is required to ensure effective control measures [228]. Since zoonoses (such as SARS and HPAI) can spread swiftly across the globe to affect global communities, coordinated surveillance approaches at local, regional, national, and international levels are essential to control zoonoses. The following four surveillance types can be practised for the control of zoonoses:

- Pathogen surveillance to detect and identify pathogens.
- Serological surveillance to detect the presence of pathogens in the blood of humans or animals through monitoring immune responses.
- Syndrome surveillance to determine the propensity of diseases through data analysis based on symptoms. This analysis-based surveillance cannot be used to identify the presence of pathogens.
- Risk surveillance to detect risk factors responsible for the transmission of disease. This control strategy cannot be used to determine the clinical features of multifarious diseases along with their prevalence.

General principles of disease control such as providing treatment to affected individuals, vaccination of healthy individuals and animals, restricting animal movement, animal population control, and testing and culling (anthrax, glanders, and Rift Valley fever) can also be used for the control of zoonoses. Decontamination of infected materials is needed to reduce the chances of acquiring new infections.

Strategies for Disease Management Planning

Concerted and multidisciplinary approaches are required for the control of emerging and re-emerging zoonoses.

1. Robust active surveillance targeting all components of the one health approach needs to be implemented for early and accurate detection of zoonoses so that effective control measures can be taken. This Surveillance includes gathering, recording and analysing data along with dissemination of these to public health management systems so that they can take effective measures for controlling the reported diseases. It also includes risk factors responsible for emergence or re-emergence such as vector biology, host dynamics, pathogen niche and virulence and socio-economic status.
2. The vector control strategies should contain a combination of physical, biological, and/ or mechanical methods including integrated pest management and integrated vector management systems.
3. Collaborations and partnerships of multi-sectoral personnel are needed for the implementation of feasible operations and surveillance among the human, animal, and environmental sectors.
4. One health concept plays a significant role in addressing emerging and re-emerging zoonoses; controlling the effect of zoonotic diseases among humans, animals, and environmental components; and making the world free from threats of zoonotic diseases.

One Health Concept

It is directly linked to the prevention and control of zoonoses. International bodies like WHO, FAO, US CDC, USDA, and EU recognise the preventive and control strategies involving the One Health Approach. The recommendations provided by one health approach to prevent and control zoonoses are:

- Developing “Zoonotic Disease Unit” for the betterment of the human and animal health agencies;
- Developing national strategy for “Zoonotic Disease Unit”;
- Engaging leadership among multi-sectoral researchers

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and relevant personnel to prioritise zoonotic disease research;
- Reviewing the zoonotic diseases on a regular basis (2–5 years) to address emerging and re-emerging diseases through regular surveillance, epidemiological implementations, and laboratory diagnosis.

Community Engagement

Strategising community engagement is essential for programme success. Community engagement has often been a critical factor in enabling successful infectious disease control and elimination programmes as was adopted in the Sichuan Province of PR China by the author. Community-driven vector control relied on high levels of active community participation in Norway rat control, which played a role in the success of the programme in ultimately lauded by the FAO of the United Nations while nominating the project for FAO Edouard Saouma Award to PR China. Strategising community engagement focuses on clearly identifying the outcomes desired from the engagement and locally appropriate ways to achieve those outcomes. Working closely with communities minimises potential negative effects of interventions, e.g. stigmatisation of particular groups or locations, and culturally and locally inappropriate packaging of health and development activities including malaria activities.

Elements that increase community engagement include: (i) increased knowledge at individual and community levels of the disease, (ii) its causality, prevention & treatment; (iii) working with communities to develop acceptable effective intervention packages; (iv) understanding and addressing the community and household incentives and disincentives for participation; (v) working with the levels of social cohesion; (vi) commitment of authorities to genuine participation and decentralisation of decision making; (vii) appropriate levels of support and resources for participation by civil society agencies. Community engagement not only ensures passive community acceptance but also builds active community participation eventually achieving community ownership of elimination. Many elimination activities require much higher levels of active community participation.

Physicians' Burn Out

Another neglected strategy is "burn out" by health providers. It is observed that 53% of physicians feel burned out by job requirements; 65% say that burnout has impacted their relationships, and other statistics say that physicians are leaving clinical medicine because of all this pressure. With the advent of new technological requirements on the job and more demands from increasingly larger healthcare organisations, the risk for burnout is even more now. Often the computer/ paperwork before and after a procedure is much longer than the procedure itself. This increases the psychological burden for physicians who may feel responsible for wrongdoing no matter which option they deem better. Hence Ben-Horin ( ) advocates diversification of work. This can include engaging in research and academics. This not only makes one, a better broad-perspective doctor but allows these health professionals to psychologically switch gears on research days. The steps include creating a well-being framework; developing the program in a way that fosters fun and connectivity among the staff; fostering individual well-being that addresses emotional and physical well-being; and creating a sustainable culture of well-being.

Preparedness to Overcome the Pandemics

The following activities will strengthen the preparedness to overcome such a pandemic.

- Active and wider zoonosis surveillance and monitoring with advanced tools like satellite-based remote sensing systems and molecular epidemiological tools.
- Disease reporting and notification service.
- Giving priority to zoonoses and action team formation.
- Available diagnostic facilities and skilled manpower.
- Cooperation at regional, national, subnational, and international levels.
- One health-based approach comprising both veterinarians and medical doctors in addition to environmental experts and other professionals.
- Ensuring adequate regular and emergency funding.
- Mass campaigning on public awareness of zoonoses.
- More research on disease epidemiology, risk factors, pathogen virulence, host biology, and vector biology.
- Wildlife monitoring and wildlife protection. Ensure safe food production of animal origin.
- Ensure the safety of infectious laboratories to avoid the accidental spread of zoonotic infections and bioterrorism.
- Protection of the environment.
- National and international educational programs to make people aware of zoonoses and hygiene.

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