PEER REVIEWED

Emerging Zoonoses: A Human-wildlife Interface?

Outbreaks of emerging zoonotic diseases have increased in the past decade and have affected the population worldwide. Often the blame for such spillover events is put on animals; however, it is humans who have ruined the balance of the ecosystem and exploited flora and fauna for their own gain. The intrusion of humans into wild habitats has increased the human-wild interface thereby increasing the chances of interspecies transmitting diseases in both directions. At the same time, globalisation has increased the likelihood of the rapid dissemination of the infection worldwide. Not wildlife but anthropogenic determinants behind the occurrence of such events should be realised and addressed vehemently.

Millions of years ago when life began on earth, numerous species emerged and co-evolved sharing earth's resources and habitat. *Homo sapiens*, which evolved as the most intelligent species, dominated and exploited the major share of resources pushing the other species towards extinction or (at the very least) struggling to thrive. Humans expanded their habitat, croplands and livestock into the forests, which disrupted the natural ecosystem and thus ruined the harmonious coexistence with other wild species. Meanwhile, broken barriers by close human-animal interfaces enabled the interspecies transmission of pathogens to distant and diverse species. Incidences of novel pathogen emergence by animal to human transmissions and the extermination of millions of humans from Earth have been witnessed on various occasions. Outbreaks from emerging infectious diseases have been reported to increase every decade since the 1980s and most of them have been linked to wildlife. Increased human-wildlife interactions brought about the recent pandemics of Human Immunodeficiency Virus, Ebola, swine flu, avian influenza, Severe Acute Respiratory Syndrome, Middle East Respiratory Syndrome, Nipah and many more. At this moment during the COVID-19 pandemic, its causative agent (SARS-CoV-2) is found to be closely related to the SARS-like coronavirus in bats[1] and we must examine the anthropogenic determinants behind such circumstances, rather than pointing our fingers towards bats or other wildlife species.

In 2019, when the whole world was busy celebrating New Year's Eve, China encountered a cluster of cases suffering from pneumonia detected in Wuhan city and linked its emergence to the Huanan wet market. Taking into account the zoonotic emergence of the disease, Chinese authorities closed those animal markets in the city and reported the incident to the World Health Organization (WHO). Within two months, the disease spread globally and caused more than 200,000 casualties out of more than 3 million cases thus far. Considering the spread and severity of the disease, WHO declared the disease as a pandemic on 11th March, 2020. A pandemic is defined as "an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people"[2]. Simply put, it includes widespread diseases causing large-scale morbidity and mortality. Pandemics not only affect public health but also disturb the sociopolitical structure of the countries. The underlying cause reported for the most recent pandemic is the emergence of a new virus or virus strain/subtype, due to genetic reassortment. These new viruses are usually highly contagious and after initial transmission from animals readily spread between humans, causing worldwide dissemination. Increased wild-human interface over the past years have increased interspecies transmission of the virus from maintenance hosts to new hosts, seen as a spillover, as well as reverting from spillover hosts to the maintenance hosts, which is known as spillback. These continuous spillover and spillback cycles have expedited the evolution of viruses where wildlife acts as reservoirs together with "living test tubes" facilitating mutation and recombination of the viruses.

Out of more than 1400 documented human pathogens, approximately 61% are considered to be zoonotic. In a study during 2007, Woolhouse and team listed out 87 novel pathogens which were reported to be pathogenic to humans during 1980–2005. Two-thirds of these were viruses and 85% had single-stranded RNA (ssRNA) genomes[3]. Most of the emerging viruses are ssRNA viruses, which lacks the proofreading capabilities of DNA polymerase or post-replication mismatch repair, leading to the high rate of error during RNA replication which is around 10 times more than DNA viruses. Most RNA viruses are zoonotic in nature as they are capable of a species jump; they were transmitted, at least initially, to humans from non-human mammals or avian hosts. Examples of RNA viruses retaining the capacity to be directly transmitted from animals to humans include influenza, Nipah, and SARS viruses, but even some viruses commonly transmitted exclusively between humans, such as HIV and hepatitis C, likely have animal origins.

Usually the interactions between wildlife and humans take place in two ways, either by the encroachment of their habitat by the human, or having an interest in wildlife tourism, souvenirs and exotic pets. The expanding human population compels intrusion of forests for human habitation, destroying wild habitats which leave wild animals concentrated in a smaller area facing a shortage of food. The dense population of wild animals in a limited area facilitates the interspecies transmission and maintenance of pathogens. Nutrient deficiency and low immunity due to food scarcity further contribute to the proliferation of the pathogens in reservoir hosts. Shortage of food pulls wildlife towards abundant food supply near human habitation bringing wildlife, livestock and human in close contact, which consequently provides a highly conducive environment for the spillover of the pathogens. An appropriate example to be cited here is, during 1998, deforestation and intensive farming of fruit trees with pig farming brought bats near fruit trees, shedding the virus to pigs through partially-eaten fruit droppings[4]. Similarly, human immunodeficiency viruses HIV-1 and HIV-2 are closely related to the simian immunodeficiency virus which was spilled over to humans by coming into contact with SIV-infected non-human primates during hunting and butchering[5]. A fancy for wildlife fur, leather, ivory and souvenirs, as well as beliefs in traditional medicines, had served as a ground for an illegal yet highly lucrative trade in wildlife, worldwide. These trade industries are known to introduce pathogens to new places along with the introduction of exotic animals and their body parts. The outbreak of monkeypox in the USA, in 2003, is a good example, where prairie dogs introduced the disease into Midwestern states of the US, by acquiring the infection from infected Gambian rats in transportation[6]. The first incidence of Marburg haemorrhagic fever was observed in the researchers of Germany in 1967, which were exposed to African green monkeys or their tissues imported

Figure 1. Animals visiting human habitation in search of food

Figure 2: Interference in animals' natural habitat via recreational activities

from Africa. Social and traditional values attached to bushmeat consumption make its hunting and trade a million-dollar industry in China and African countries. In the past 20 years, poaching of gorillas for bushmeat has reduced its population to half in forests in the Democratic Republic of Congo. In 1970, the first incidence of monkeypox virus disease to human was linked to non-human primates hunting followed by human-to-human transmission[7]. The outbreak of Ebola in Gabon in 1995 emerged from the handling, preparation and consumption of meat from chimpanzees found dead[8]. Intensely dense live animals' markets, also known as wet markets, bring different animal species into close contact, where butchering of an infected animal contaminates the environment with blood spills, which thus provide a highly favourable environment for interspecies transmission and mutations of pathogens. Wet markets in Southeast Asian countries had contributed to the emergence and spread of highly pathogenic avian influenza H5N1 in 2006. Outbreaks of Severe Acute Respiratory Syndrome (SARS)[9] in 2003 and ongoing COVID-19[10] have also been linked to the trade in civet cats and pangolins, respectively, in Chinese wet markets. New trends of captivating wildlife in the name of exotic pets bring human and wild animals under the same roof, increasing the duration of exposure and odds of disease transmission.

Despite the emergence of deadly pandemics with wild-human interactions, the control measures for minimising human interference are either inadequate or infringed very frequently. Stringent laws on killing, captivity and trade of wild species must be framed and employed rigorously. Preservation of natural habitats of wildlife must be undertaken and injudicious cutting or burning of forests must be prohibited. Human access for livestock grazing, hunting or other recreational activities must be minimised in the buffer zone and strictly restricted in core forest regions. Despite the reports stating wildlife as reservoirs of many pathogens, there is a dearth of monitoring, surveillance and baseline data of diseases in wild animals. Lack of baseline data on disease and population of wildlife in an area render the health authorities incapable of identifying the source of disease. Wildlife

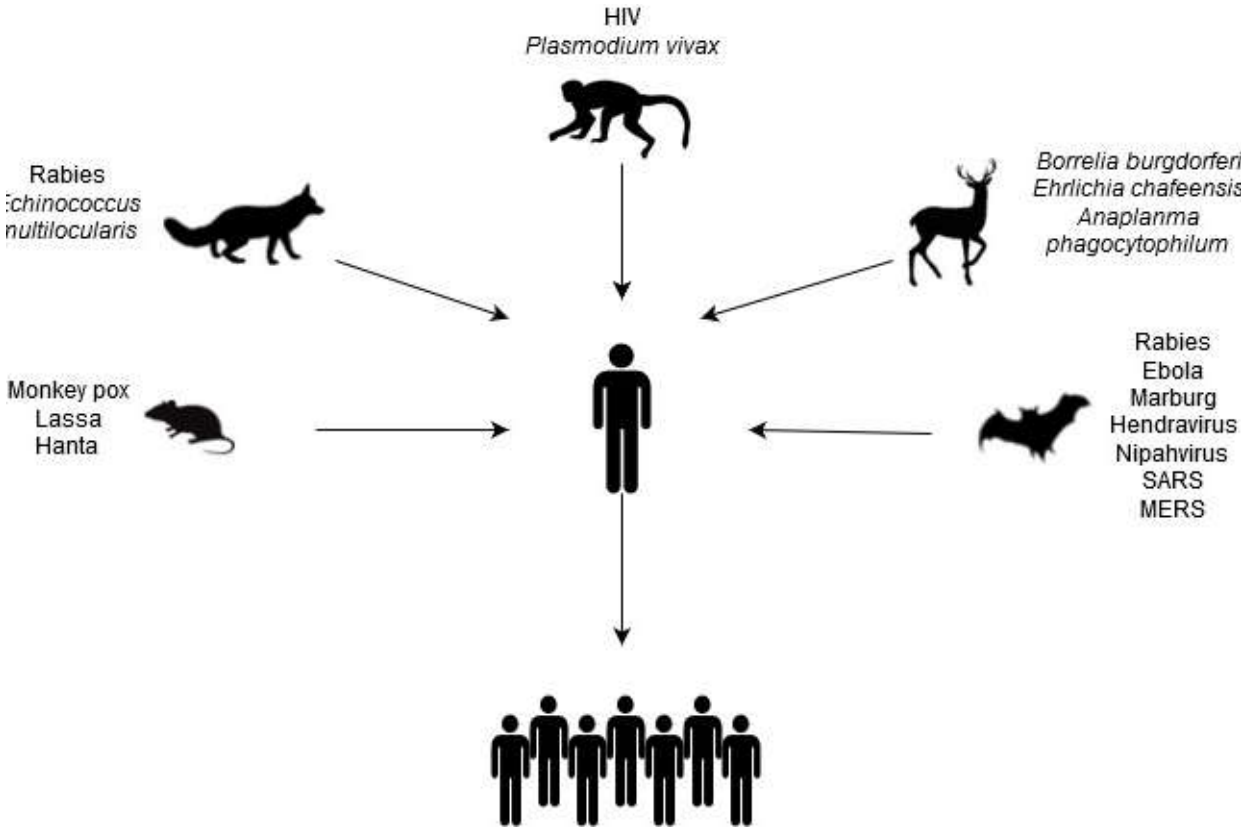

Figure 3: Schematic representation of common emerging zoonoses from wildlife

surveillance requires a multi-sectoral approach, including native people, animal health agencies, public health agencies and forest departments. Adequate awareness of people interacting with wildlife is needed to facilitate the monitoring and data gathering. Adequate active and passive surveillance of transmission, carriers and reservoirs of diseases in wildlife is an essential precondition for rapid identification of a spillover. Latest models to predict future spillovers ahead of time must be employed in surveillance studies. Measures like diagnosis, treatment, vector reduction and vaccination in wild animals must be taken to reduce the pathogen load and diminish the likelihood of disease transmission to human.

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