Zoonosis in Cancer Patients

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Muhammad Akbar Khan[1], Hazrat Bilal [2], Ahmad Abdullah[3], Tayyba Ashraf [4], Sibgha Akram[5], Ifrah Tahir[4], Sofia Qassim[6], Sania Rasheed[1], Saira Sarwar[7] and Umera Nawaz[1]

ABSTRACT

Zoonoses, which constitute a significant portion of emerging human infections, have been estimated to originate from wildlife in over 70% of cases. The prevalence of zoonotic diseases presents a global public health concern, with impoverished livestock workers in low- and middle-income nations being particularly vulnerable. These zoonoses result in billions of instances of illness and millions of fatalities annually. The chapter delves into the relationship between cancer and the immune system, emphasizing the challenges faced by cancer patients in mounting effective immune responses. Furthermore, it explores the intriguing link between pet ownership and the risk of developing cancer, shedding light on specific associations between certain pets and types of cancer. The transmission routes of zoonotic infections, the diversity of common zoonotic pathogens, and the challenges in diagnosing and managing these infections are thoroughly examined. The impact of cancer treatment on the immune response is explored, emphasizing the importance of understanding immunological dynamics during therapy. In conclusion, this chapter synthesizes information on zoonotic diseases, cancer, and immunology, providing valuable insights into the complex interactions between humans, animals, and the environment. The recommendations and research perspectives presented contribute to a deeper understanding of these interrelated topics, with implications for global health management and the prevention of zoonotic infections.

Keywords: Zoonotic diseases, Cancer, Pet ownership, Transmission routes, Vaccination

CITATION

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[1]Department of Life Sciences, University of Management and Technology, Lahore
[2]Department of Medical Lab Technology, Hazara University Mansehra
[3]M.B.B.S, HBS Medical and Dental College, Islamabad
[4]Department of Parasitology, Faculty of Veterinary Sciences, University of Agriculture, Faisalabad
[5]Department of Chemistry, Faculty of Basic Sciencs, University of Agriculture, Faisalabad
[6]Department of Zoology, University of Education Lahore, Faisalabad Campus
[7]Department of Biotechnology, Faculty of Life Sciences, University of Central Punjab, Lahore
***Corresponding author:** akberniazi5@gmail.com

1. INTRODUCTION

The interactions among humans, animals, and the environment influence the emergence and transmission of various infectious diseases. The majority of infectious diseases that impact the human population originate from animals. According to the report titled "Asia Pacific Strategy for Emerging Diseases: 2010," it was estimated that approximately 60% of emerging human infections are zoonotic (Thompson and Kut 2019). Furthermore, it was found that over 70% of these pathogens originated from wildlife. The emergence of novel diseases in humans during recent decades has been attributed to zoonotic transmission, wherein the diseases originate in animals and are directly linked to the intake of animal-derived food products (WHO 2011).

The term "Zoonosis" originates from the Greek word "Zoo," denoting animal, and "nosis," signifying illness. As per the classification provided by the World Health Organization (WHO), zoonosis refers to any disease or infection that can be transmitted naturally between animals and humans, or vice versa. Approximately, 61% of human pathogens exhibit zoonotic characteristics (Slingenbergh et al. 2013). Fig. 1 shows how zoonotic diseases impact human being.

Zoonosis poses a significant public health concern and represents a direct threat to human health, with potentially fatal outcomes. The impact of the 13 most prevalent zoonoses worldwide has been particularly pronounced among impoverished livestock workers residing in low-and middle-income nations. These zoonoses have resulted in an estimated 2.4 billion instances of illness and 2.7 million fatalities in human annually. Most of these diseases harm animal well-being and result in a decline in livestock productivity (Grace and Ogutu 2012).

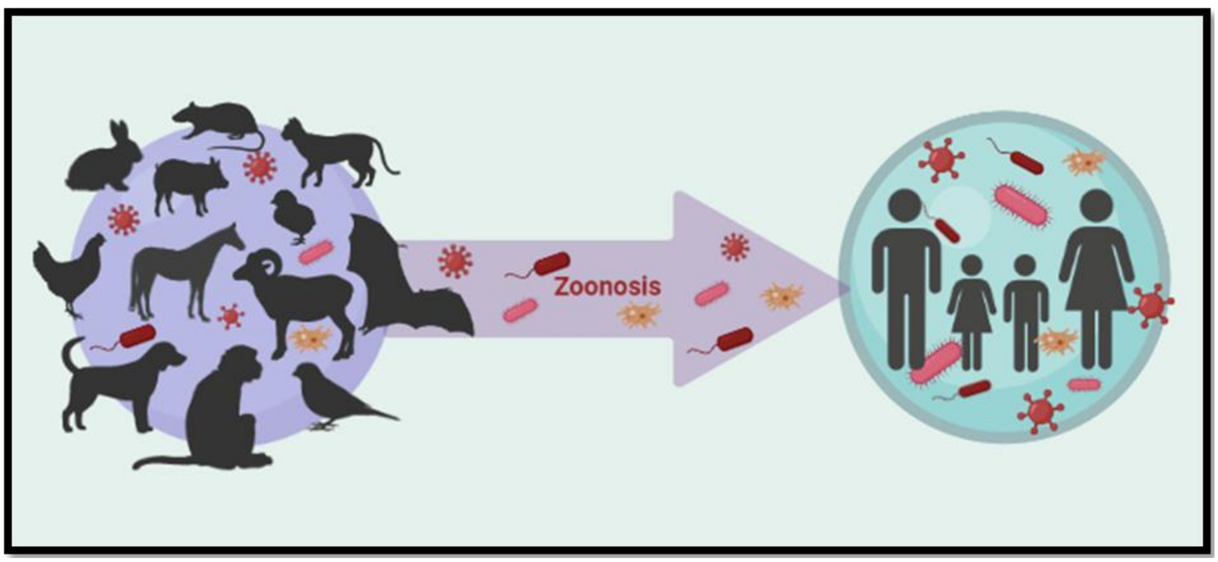

Fig. 1: An infograph on zoonosis. Image retrieved from BioRender.

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2. UNDERSTANDING THE CANCER

Cancer is a pathological state characterized by the aberrant behavior of a cluster of cells that defy the normal regulatory mechanisms regulating cellular proliferation, resulting in unrestrained growth. Cancer cells exhibit a lack of responsiveness to the signals that typically trigger the regular cell cycle. This is due to their inherent self-sufficiency, which ultimately results in the unregulated expansion and multiplication of affected cells. If the uncontrolled growth and division of malignant cells persists, it has the potential to result in a lethal outcome (Waks and Wine 2019). Indeed, it is worth noting that a significant proportion, approximately 90%, of mortalities resulting from malignancies can be attributed to the phenomenon of cancer cell dissemination to distant structural sites, a process commonly referred to as metastasis (Cleator et al. 2007).

During mitosis, the cellular division process, normal cells exhibit interdependence by relying on the presence of external growth factors for their development. If the availability of these growth signals becomes restricted or ceases altogether, cellular replication comes to a halt. In contrast, tumor cells exhibit autonomous growth without any external factors or signaling indicators. Additionally, it is worth noting that normal cells possess a remarkable capacity for contact inhibition. Cell division stops when a sufficient number of neighboring cells are detected, specifically upon reaching a specific threshold (Coffey et al. 2003). In contrast, cancer cells exhibit a deficiency in contact inhibition, resulting in the development of an undesirable aggregation of cellular masses. The existence of a typical cell is intricately regulated; it undergoes approximately 50 rounds of division before undergoing apoptosis, ultimately giving way to cellular renewal through the emergence of another cell. This phenomenon can be attributed to the inherent constraints of DNA replication, which result in a slow degeneration of telomeres due to repeated replication events. In contrast, cancer cells exhibit heightened telomerase enzyme activity, which consistently regenerates the damaged and weakened telomere ends. This relentless renewal process enables unrestricted cellular proliferation (Abbas and Rehman 2018).

3. CANCER AND IMMUNE SYSTEM

Patients with cancer often develop immune responses that specifically target their tumors. While natural killer (NK) cells and tumor-infiltrating lymphocytes work together to attempt to eradicate cancer cells, they are ultimately unsuccessful because cancer cells may avoid efficient immunosurveillance. First, tumor cells generate an interleukin-2 (IL-2) environment that inhibits NK cell division, T-helper cell proliferation, and T-cytotoxic cell proliferation and function by producing immunosuppressive cytokines and prostaglandins. This shifts the immune response toward a Th2 response, in a humoral response with significantly fewer antitumor capacities (Reiche et al. 2004). Second, antigenicity-reducing major histocompatibility complex class I and II and antigen-processing mutations in malignant cells are selected, leading to variations of the cells that are resistant to the immune system. Last but not least, cancer cells may kill T-cells themselves by activation-induced cell death or by launching a counterattack through Fas ligand production (Loose and Van de Wiele 2009).

4. PETS OWNERSHIP AND THE RISK OF DEVELOPING CANCER

There are several known human carcinogens in the environment (ultraviolet light, radon gas, infectious agents, etc.) and in working environments (asbestos, silica dust, diesel engine exhaust, and wood dust). Birds and lung cancer, dogs and breast cancer, and cats and brain tumors or hematological malignancies have all been related to exposure to pets in certain research. Avian exposure was shown to be an independent risk factor for lung cancer in three European studies conducted in the late 20th century (Hemsworth and Pizer 2006). One of the first researchers to look at whether or not keeping birds as pets increased the likelihood of developing lung cancer was Holst et al. (1988). In a case-control study, each of the 49 patients with lung cancer who were 65 years old had their ages and sexes matched with two control participants from the same primary care clinic. Economic status, cigarette smoking, alcohol usage, and vitamin C intake were also measured. Lung cancer risk was shown to be strongly and independently associated with smoking, raising birds, and a deficiency in vitamin C. The chance of acquiring lung cancer was elevated by a factor of 6.8 for those who worked with birds. Almost a decade later, Kohlmeier also reported that having a pet bird was a distinct risk factor for lung cancer based on a German case-control study (Elad, 2013). Between April and October of 1990, researchers in West Berlin interviewed 239 people who had just been diagnosed with cancer of the lungs, trachea, or bronchi. Interview included eight primary topics: healthy living, diet, smoking (both active and passive), pet ownership, workplace exposure to lung carcinogens, current health, and demography. Using the same methods as Holst's study, Kohlmeier discovered a relative risk increase of 2.14 (95% confidence range of 1.35 to 3.40) among those who were in contact with pet birds. While having budgerigars or a canary at home has been linked to an elevated risk of lung cancer diagnosis (odds ratio 3.53, 95% confidence range 1.56 to 7.98). A more recent British research by Gardiner found that keeping pigeons at home was the sole relevant connection (Gardiner et al., 1992). However, it is believed that hypersensitivity pneumonitis brought on by exposure to bird allergens and particulate matter leads to pulmonary interstitial fibrosis and/or dysfunction in the lung macrophages, which may be the exact pathogenesis linking regular avian exposure at home and lung carcinoma (Odendaal, 2000).

5. TRANSMISSION ROUTE OF ZOONOTIC INFECTION

The transmission of pathogens from animals to humans may be either direct or indirect. Direct zoonosis means animal diseases that may spread from animals to humans through the air includes diseases like avian influenza that are transmitted directly from animals to humans through airborne droplets or fomites (Cantlay et al. 2017). Rabies, one of the worst zoonotic illnesses, is spread from infected animals to vulnerable people via bites. The Rhabdoviridae family of viruses is responsible for this disease. The saliva of a rabid dog, bat, monkey, skunk, raccoon, or fox is the vector by which the virus enters a human host. Dengue fever is an example of a disease that may be spread from animal to human through a vector.

Most or all of zoonotic pathogens proliferate in the intestines and are lost in feces many can multiply extensively in tissue, with catastrophic outcomes, and may be transmitted indirectly from animals to humans. Spores released into the environment from bodily waste or decaying animal tissue greatly enhance the prevalence of pathogens that may infect humans. However, infected animals are unlikely to serve as much more than multiplicating hosts, and the organisms do not satisfy the requirements for classification as zoonotic infections (Songer 2010).

6. COMMON ZOONOTIC PATHOGEN

Zoonotic diseases are categorized based on their etiology. Bacterial zoonosis encompasses diseases like anthrax, salmonellosis, tuberculosis, lyme disease, brucellosis, and plague. Viral zoonosis includes rabies, acquired immune deficiency syndrome (AIDS), ebola, and avian influenza (Chomel and Sun 2011). Parasitic zoonoses consist of diseases such as trichinellosis, toxoplasmosis, trematodes, giardiasis, malaria, and echinococcosis. Fungal zoonosis is represented by ringworm. Rickettsial zoonosis includes Q-fever, while chlamydial zoonosis represents psittacosis. Mycoplasma zoonosis refers to *Mycoplasma pneumoniae* infection. Protozoal zoonosis involves diseases caused by protozoa. While diseases caused by acellular non-viral pathogenic agents include transmissible spongiform encephalopathies and mad cow disease (Rahman et al. 2020). Table 1 highlights the major zoonotic diseases, their host, etiology and symptoms.

Table 1: Major Zoonotic Diseases their Host, Etiology, and Symptoms.

Disease	Etiology	Animal Host	Symptoms and Organs involved
		Bacterial Zoonosis	
Tuberculosis	*Mycobacterium bovis, Mycobacterium microti Mycobacterium caprae,*	Cattle, camels, swine, wild boars, and bison	Respiratory organs bone marrow
Campylobacter fetus infection	*Campylobacter fetus , Campylobacter fetus testudinum*	Cattle, goat, and sheep	Enteric disorder
Helicobacter infection	*Helicobacter pullorum, Helicobacter suis*	Poultry and pigs	Peptic ulcer
Salmonellosis	*Salmonella enterica, Salmonella bongor*	Domestic animals, dogs, and birds	Enteritis
Parasitic Zoonosis			
Cryptococcosis	*Cryptococcus neoformans*	Cattle, dog, wild animals, birds, sheep, goat and horse	Respiratory problems, fever, nausea, and vomiting
Cutaneous larval migrans	*Ancylostoma braziliense*	Cats and dogs	Subcutaneous tissue
Hydatidosis	*Echinococcus granulosus*	Buffaloes, sheep, goats, and adult stray or shepherd dogs	Hydatid cysts in the lungs, kidneys, bones, liver, and spleen
Viral Zoonosis			
AIDS	HIV Genus—*Lentivirus* Family—*Retroviridae*	Monkeys and chimpanzees	Immunosuppression, fever, chills, night sweats, rash, swollen lymph nodes and fatigue
SARS	SARS-CoV Genus-*Coronavirus* Family-*Coronaviridae*	Bats, lions, tigers, dogs, minks, and cats	Influenza-like symptoms include muscle pain, fever, pneumonia,
Dengue fever	Dengue virus Genus—*Flavivirus* Family—*Flaviviridae*	Dogs and monkey	High fever, skin hemorrhage, skin rash, and shock
Fungal Zoonosis			
Ringworm infection	*Microsporum spp., Trichophyton spp.*	Cat, sheep, cattle, dog and goat	Skin lesions
Malassezia infection	*Malassezia spp.*	Cat and Dog	Atopic eczema, seborrheic dermatitis, folliculitis, Pityriasis versicolor, and dandruff
Aspergillosis	*Aspergillus spp.*	All domestic birds and animals	Respiratory problems
Histoplasmosis	*Histoplasma capsulatum*	Rat, rabbit, cat and dog	Often asymptomatic, but may exhibit the symptoms like fever, chest pain, hepatosplenomegaly, weight loss, and hematologic disturbances

7. IMPAIRED IMMUNE RESPONSE IN CANCER PATIENT

Individuals exhibiting immunological deficiencies or those whose immune systems are not fully matured, such as children under the age of five, elderly individuals aged 65 years and more, expecting mothers, and cancer patients with medical conditions or undergoing treatments that suppress immune function, are more susceptible to contracting diseases associated with pets (Stull et al. 2013). Nevertheless, the groups of pet ownership practices and the frequency of their interactions with animals are generally comparable to what is observed in the broader population. The ownership of pets, as well as the specific species involved, in households with children who have compromised immune systems and children under the age of 5, are comparable to that of households with children who have fully functional immune systems (Stull et al. 2014).
Recommendations associated with the ownership and interaction with animals have been documented for individuals belonging to high-risk categories, as supported by scientific literature references (Mani and Maguire 2009). Furthermore, supplementary guidelines focusing on animal-assisted interventions within healthcare establishments are also accessible. Considering the advantageous effects of animal companionship on human health and the understandable attachment patients have toward their pets, it is imperative to emphasize the significance of adhering to particular preventive measures. Individuals divided as being at greater risk and their respective domestic units must maintain greater concern regarding the well-being of their companion animals and implement measures to decrease the potential transmission of pathogens. Due to the limited efficacy of animal vaccines in minimizing zoonotic disease transmission, it becomes imperative to explore alternative approaches for minimizing the incidence of pet-related illnesses. The guidelines about pet contact include various aspects such as personal hygiene, the classification and developing stages of organisms, as well as the practices related to the well-being and care of pets (Lefebvre et al.2008).

8. EFFECT OF CANCER TREATMENT ON IMMUNE RESPONSE

Immunotherapy is the most quickly developing field in clinical oncology right now, and it offers the unique possibility of treating and even curing several cancers that were previously incurable. It is becoming clearer that inducing a long-lasting anticancer immune response is essential to the efficacy of chemotherapy and radiation in maintaining disease stabilization (and even cure) long after treatment has been stopped. (Sangro et al. 2021). Indeed, there are dynamic changes in the local immunological infiltration that precede the transition from a preexisting immune response to an immune response generated by treatment. Thus, the immunological contexture, which is established by the tumor's leukocyte infiltrate's density, composition, functional state, and organization, might provide insights into the disease's prognosis, the likelihood of a treatment's success, and other pharmacodynamic factors. Several different tools may be used together to learn more about the immunological context of tumors, identify biomarkers that may help tailor treatments to each particular patient and track their progress while on anticancer drugs (Fridman et al. 2017).

9. INCREASED SUSCEPTIBILITY TO ZOONOTIC INFECTIONS

Zoonotic diseases have exhibited an increasing prevalence owing to a multitude of factors, encompassing urbanization, deforestation, tourism, zoological establishments, climate change, and the poaching of wildlife. These factors have significantly altered the dynamics of daily existence and interactions between animals and humans Led to a surge in the interaction between humans and animals as shown in the Fig. 2 retried from BioRender (White et al. 2020).

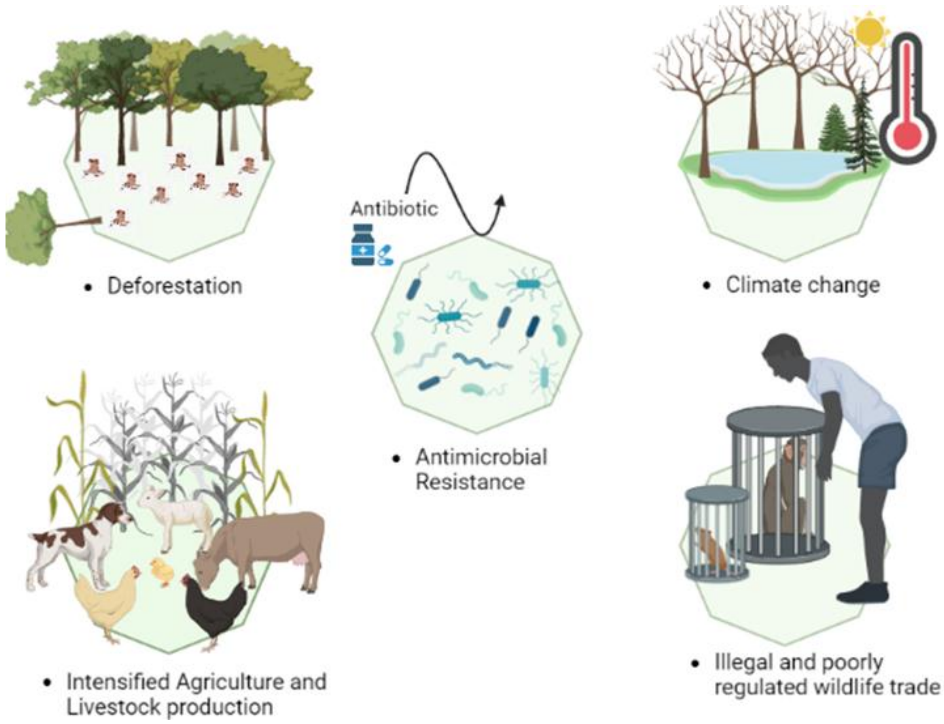

Fig. 2: Factors that cause Zoonotic Emergence.

As natural habitats diminish, animals are compelled to explore human settlements, thereby intensifying the potential for disease transmission. The phenomenon of wildlife trade has also increased contact, which can manifest at various stages of the trade process, ranging from transportation to consumption. All of these factors exhibit similarities in their contribution to the progression of zoonotic disease emergence, while also presenting distinct challenges (Cavallero et al. 2021). One of the recurring themes observed in the context of human-related factors influencing zoonotic diseases is the phenomenon of animals that were previously situated in remote areas, such as the canopy levels of forests, being compelled to engage in interactions with humans at ground level. Moreover, the alterations in the ecological landscape have resulted in the modification of temperature and moisture levels within the surrounding environment (Sabin et al. 2020). These changes can be observed not only due to climate change but also as a consequence of deforestation, which leads to the formation of sunlit pools in areas that have been cleared. Because of these changes, vectors that spread disease proliferate, and animals relocate closer to human populations to take multiple advantage of safety and availability of food given by the shifted environments. Continuing the investigation of these patterns and unraveling the complexities of human-animal interactions and transmissions is of the greatest importance to enhance the formulation of policies, urban risk reduction management strategies, such as pest control, public health education, environmental sanitation initiatives, and preventive measures aimed at mitigating future outbreaks (Ahmed et al. 2019).

10. INFLUENZA

10.1. AVIAN INFLUENZA

Domestic cats are infected with H5N1 flu in Europe (Austria, Germany) and many Asian countries. Captive tigers at a Thai Zoo also fell victim to the disease. Tigers were fed the flesh of avian flu H5N1-infected chickens. There are few reports of H1N1 infection in cats in the United States and Italy (Harder and Vahlenkamp 2010). In South Korean during 2007 pet dogs were reported to have been exposed to an epidemic of avian influenza H3N2. There is no evidence that the H3N2 outbreak afflicting greyhounds in the United States is zoonotic, even though it is linked to an equine influenza virus. It seems that cats and dogs have little role as potential vectors of human illness. Experimental infection was successful in infecting cats, and infected animals were able to spread the disease to uninfected cats. Dogs seem to have an even less role in the transmission of avian flu to people. As was hypothesized for the H1N1 virus, it is more likely that people are the vector of infection for pets (Sponseller et al. 2009).

10.2. SWINE FLU

The H1N1 Swine Flu is a strain of influenza virus, which can spread from person to person and cause a variety of unpleasant symptoms, including a runny nose, a high temperature, a loss of appetite, and possibly pneumonia. Swine flu, or H1N1 swine influenza, is a viral respiratory illness that mostly affects pigs. Swine influenza A (H1N1) causes respiratory illness that may infect pigs' respiratory systems. Swine flu (zoonotic swine flu) has sometimes been transmitted to humans via close interactions with pigs. If the antigenic features of swine flu viruses alter due to reassortment, they might infect humans. When this occurs, is often ineffective in spreading the disease. If influenza spreads from person to person and becomes efficient we might see another pandemic like that in 1918 and 2009 (Farley 2010).
Around 500 million people were infected with the H1N1 influenza virus in 1918, making it one of the deadliest pandemics in human history. Around 50 to 100 million people (3 and 5 percent of the global population) died as a result of the pandemic. The WHO declared a pandemic in 2009 due to the rapid global spread of a novel H1N1 strain of swine flu (Dhamma et al. 2012). Since 2009 H1N1 strain was not transmitted from pigs to people and it cannot be classified as a zoonotic swine flu. Instead, it was conveyed by respiratory droplets from person to person, touching infected surfaces and then touching one's eyes or nose. Reassortment of the viral RNA structure may have facilitated human-to-human transmission of this virus, which induced symptoms identical to those reported in pigs. Although it may seem like consuming pork products (like bacon or ham) will not give you swine flu (Sinha 2009).

11. BACTERIAL INFECTION

11.1. CAMPYLOBACTER JEJUNI

The manifestation of self-limiting gastrointestinal distress, including diarrhea, vomiting, and fever, is frequently observed in cases of *Campylobacter jejuni* infection. Consistent episodes of septicemia and diarrhea are more common in high risk patients (Tenkate and Stafford 2001). Various domesticated species can transmit *C. jejuni* in dogs and cats. These animals can excrete infectious microorganisms through their fecal matter. Young canines and felines exhibit a higher propensity for shedding Campylobacter species compared to their adult counterparts, and the acquisition of a young pup or kitten is linked to the greatest likelihood of transmission (Gras et al. 2013).

11.2. SALMONELLA SPECIES

In individuals with a fully functional immune system, salmonellosis typically manifests as a self-restricting gastrointestinal ailment, although severe manifestations can occur. The disease demonstrates increased severity in individuals with heightened susceptibility, resulting in severe systemic and localized infections, such as neonatal meningitis and osteomyelitis in individuals with sickle cell anemia. Different pet species have been linked to the potential transmission of diseases to humans including amphibians, reptiles, exotic animals, rodents, and young poultry demonstrating the greatest inclination for presenting risks in this context (Mermin et al 2004). Reptiles and amphibians are hypothesized to play a role in approximately 11% of sporadic Salmonella infections observed in individuals below the age of 21. It is worth noting that direct interaction with these animals is not necessary for the transmission of zoonotic diseases. In a particular investigation, it was observed that 31% of cases involving salmonellosis associated with reptiles were found in individuals below the age of 5, with 17% occurring in children who were 1 year old or younger. These results emphasize the increased vulnerability of children to this condition and the possibility of transmission of reptile-associated Salmonella even in the absence of direct interaction with the reptile or its habitat (Whitten et al. 2015). Recent reports have indicated the occurrence of pet-associated salmonellosis outbreaks, involving various species such as hedgehogs, rodents, young poultry, frogs, and turtles. A significant proportion of these cases (35 to 70%) have been observed in children. Furthermore, a multitude of animal-derived sustenance, including uncooked flesh, uncooked ovum, and uncooked delicacies such as swine auricles, are frequently found to be tainted with members of the Salmonella genus. The consumption of these products has been firmly established as a significant risk factor for the development of salmonellosis in domesticated animals, and there have been documented instances of human outbreaks associated with this phenomenon (Leonard et al. 2011).

12. PARASITIC DISEASES

12.1. CRYPTOSPORIDIUM SPECIES AND GIARDIA DUODENALIS

Subclinical or self-limiting diarrheal episodes are commonly observed in cases of cryptosporidiosis and giardiasis, accompanied by weight reduction and the presence of chronic diarrhea in individuals at a higher risk. The manifestation of symptoms in cases of cryptosporidiosis can exhibit variability based on the specific species or genotype of the infecting organism. While it is true that the majority of Giardia assemblages exhibit species-specificity, there exist certain assemblages that have been observed in both animal and human hosts, demonstrating documented instances of zoonotic transmission. Various pet species have been found to potentially host zoonotic Cryptosporidium and Giardia, such as puppies and kittens, which can excrete these organisms in their excretion (Stull et al. 2015).

12.2. TOXOCARA SPECIES

Toxocara, a type of roundworm, generally manifests as either subclinical or self-limited disease in human. However, it is important to note that a small subset of patients may experience the development of ocular or visceral larva migrans. Young children are at the greatest risk due to their heightened susceptibility to a greater amount of infectious material following the consumption of dog or cat feces containing eggs (Lee et al. 2014). Due to the regular deworming practices observed in most domesticated animals, the maturation of larvae into an infective stage typically takes two to three weeks following their excretion in fecal matter. Consequently, the greatest likelihood of exposure arises from interactions with soil that have been contaminated by untreated or feral animals' waste. Such situations commonly occur in areas like sandboxes, gardens, or playing fields (De Boer et al. 2007).

12.3. TOXOPLASMA GONDII

The most frequently observed symptoms following infection with *Toxoplasma gondii* in individuals with a fully functioning immune system are subclinical or self-limited febrile illness and lymphadenopathy.

Toxoplasmosis poses the highest level of concern in pregnant women who have not previously developed immunity, as well as in individuals with compromised immune systems, irrespective of their exposure history (Mani and Maguire 2009). In these individuals, the infection can lead to the occurrence of congenital abnormalities, as well as encephalitis or meningitis. Cats, with their role as the definitive host, play a crucial role in the life cycle of *T. gondii*. On the other hand, humans primarily acquire infections from this parasite through food consumption and environmental exposure (Esch 2013).

13. VIRAL INFECTION

13.1. RABIES

Canis lupus familiaris, commonly known as dogs, serve as the primary reservoir species for the transmission of the viral disease known as rabies. These canines typically transmit the virus through an unprovoked biting behavior. Wild mammals, including foxes, raccoons, skunks, and wolves, serve as reservoirs in specific regions, while bats are infected with lyssa virus in all areas where they have been studied. The etiological agent responsible for the vast majority, approximately 99%, of human fatalities is the canine rabies virus. Rabies poses a susceptibility to all mammals, rendering them potential vectors for the transmission of the virus. This includes feline species, as well as other domesticated animals. However, it is worth noting that monkeys, while very rarely, can also serve as vectors for rabies transmission. Rodent-induced bites pose a minimal risk (WHO 2013).

The prompt for early identification relies on extracting a chronicle of an encounter with a potentially infected mammal, typically occurring in regions of Asia, Africa, or South America where dog rabies prevails. A diverse array of non-specific prodromal symptoms has been observed in individuals with rabies, leading them to seek medical attention from various specialists including rheumatologists, neurologists, psychiatrists, cardiologists, respiratory and acute medicine physicians, ear, nose, and throat specialists, general and transplant surgeons, as well as general practitioners. In the absence of intensive care, individuals who have not received vaccinations and are afflicted with furious rabies encephalomyelitis collapse within a couple of days. In contrast, patients suffering from paralytic rabies may exhibit survival for several weeks (Gautret et al. 2014).

13.2. MONKEYPOX

During May of 2022, the World Health Organization declared a worldwide pandemic of human monkey pox. As of September 21, 2022, 64,290 incidents of monkey pox were confirmed by laboratories across 106 nations, resulting in 20 deaths. The swift increase of the epidemic has coincided with the emergence of a new viral pandemic and public health concern (Wenham and Eccleston 2022).

More than 60 years ago scientists discovered that the monkeypox virus (MPXV) was the cause of monkeypox sickness. In 1959, a report detailing two outbreaks of pox-like illness in *Macaca fascicularis* monkeys at Statens Serum Institut in Copenhagen, Denmark, was published. This was the first time that monkeypox had been documented (Sklenovská and Van Ranst 2018). A newly identified poxvirus, which came to be known as monkeypox, was blamed for these epidemics. Several further outbreaks of monkeypox in zoos and research facilities involving captive monkeys have been documented. In 1970, a 9-month-old boy in the Democratic Republic of the Congo was the first person to be diagnosed with monkeypox virus (MPXV) infection. Since then, researchers have shown monkeypox to be endemic in parts of Central and Western Africa. Human-to-human transmission of MPXV has previously been described in endemic areas in Central Africa, therefore this epidemic is not unprecedented. The 2003 epidemic in the United States (US) is only one example of a non-endemic country experiencing a monkeypox outbreak that was likely caused by imported animals from an endemic zone. The history of monkeypox epidemics has shown the world how important this new zoonosis (Beer and Rao 2019).

The increasing incidence of monkeypox during the last 40 years has been attributed to several variables. One of these variable is increased vulnerability to monkeypox infection after smallpox immunization was discontinued. The efficacy of smallpox immunization in preventing monkeypox is estimated to be about 85%. Consumption of large quantities of animals—potential MPXV reservoirs—may also have a role, especially in areas hit hard by poverty and societal upheavals like civil wars. The increasing human density, the convenience of travel, and ecological and climatic variables (such as the clearance of tropical rainforests) that enhance the danger of exposure to reservoir animals have all been related to the onset of monkeypox epidemics (Rimoin et al. 2010).

14. REVIEW OF ZOONOTIC INFECTION IN CANCER PATIENT

There is still a lack of understanding about the course and effects of severe H1N1 influenza infection in cancer patients. Hajjar et al. (2012) reported on eight incidences of H1N1 infection among patients at a referral cancer center's critical care unit of Estado de São Paulo hospital associated with Universidad de Sao Paulo Medical School in Brazil.

All hospitalized patients with acute respiratory failure from novel H1N1 infection were analyzed for their clinical data. All those who died had autopsies, and viral and bacterial tests by real-time RT-PCR were performed on lung tissue (Hajjar et al. 2012)

A total of eight patients, aged 55 to 65, were hospitalized. There were a total of five patients, three of whom had hematological malignancies and two of whom had solid organ tumors. All five individuals who needed ventilators ultimately passed away. Bronchopneumonia caused by bacteria affected four people. Multiple organ failure was the cause of death in each case. The three survivors all had a less severe type of lung ailment. All patients had a lung tissue examination, which revealed diffuse alveolar injury in the majority of cases. Necrotizing bronchiolitis and massive bleeding were also seen in the lungs (Hajjar et al. 2012).

In cancer patients, an H1N1 virus infection may quickly progress to a life-threatening disease known as acute respiratory distress syndrome. To further understand what factors can indicate a worse outcome for these individuals, more data are required (Hajjar et al. 2012).

15. TREATMENT OF ZOONOTIC INFECTION

Animals with zoonotic illnesses are treated in the same way as those with non-zoonotic diseases, although therapies that delay the shedding of zoonotic organisms should be avoided unless necessary. In cases of simple Salmonella-associated diarrhea, for instance, antibiotic therapy is often not recommended since it may delay the shedding of the offending bacteria. On the other hand, where the infection is subclinical or predicted to self-limit, such as a mild skin lesion due to dermatophytosis, animals that contain zoonotic infections may occasionally be treated to reduce human exposure (Lafaye and Li 2018).

Human infection should be avoided at all costs for the treatment of zoonotic illnesses. The decision of whether to keep the animal at home or in a hospital, requires professional judgment. Considerations include the possible impact of the illness on people, the vulnerability of household members, and the efficacy of barrier nursing, sanitation, and hygiene measures when carried out by humans. If the pathogen may continue in a latent or chronic, subclinical form after treatment, the owner should be fully aware of this. When the animal's life is in danger due to a zoonotic illness, euthanasia may be the only option (Colella et al. 2018).

People who suspect they have caught a zoonotic illness should see a doctor as soon as possible. If the condition is rare and not often on a doctor's radar, it is very important to provide the doctor with as much information as possible to help with the diagnosis. It is preferable to eliminate the infection from both the animal and human hosts at the same time. Public health officials must be notified of the presence of certain zoonotic illnesses, such as rabies (Edwards et al. 2020).

16. CHALLENGES IN DIAGNOSIS AND MANAGEMENT

If there are no BSL-3 laboratories accessible, you should not use any diagnostic technique that involves BSL-3 category live organisms, including culture growth or enrichment. However, even under BSL-2 conditions, the accidental culture growth of pathogens like *Bacillus anthracis* may occur if there is not enough clinical evidence. Infections in the lab may be avoided by adhering to standard operating protocols, limiting opportunities for direct contact, and using hand hygiene products (Weber et al. 2003).

Serology, conventional microscopy, and molecular techniques might be considered if cultural approaches must be avoided for safety concerns. Testing is best done using inactivated samples if the diagnostic methods have been verified with them.

Wherever feasible, inactivated biological material should be used in diagnostic processes. Inactivation protocols that have been shown effective vary by pathogen type. Mycobacteria, for example, have spores and cell walls that contain mycolic acid, making them very resistant to environmental factors and inactivation processes. Mycobacterium spp. can be killed by exposing them to temperatures above 65°C, ultraviolet (UV) light, ethylene oxide, formaldehyde vapor, chlorine compounds, 70% ethanol (in non-protein-containing materials), 2% alkaline glutaraldehyde, peracetic acid, iodophors (depending on the presence of organic matter), and stabilized hydrogen peroxide (Logan et al. 2011).

To effectively kill anthrax spores, a solution of either 5% formaldehyde or glutaraldehyde, a 1:10 dilution of home bleach adjusted to a pH of 7, or a 500 mg/L chlorine dioxide aqueous solution is used. As was recently established for rickettsiae, testing for dependable inactivation should include titration of the least harsh, yet safely inactivating technique and the assessment of time-inactivation curves (Frickmann and Dobler 2013).

Diagnostic methods that come after inactivation techniques that are too harsh might be compromised. For instance, if a considerable amount of human DNA is released from the sample, or if heme is released from lyzed erythrocytes, the PCR reaction may be inhibited. Therefore, the whole pre-analytic process, including the diagnostic method, must always be reviewed simultaneously to guarantee consistent outcomes. Pre-analytical processes that have been thoroughly tested must be maintained in an operational diagnostic context (Alaeddini 2012).

When a crucial pathogen cannot be isolated and put through a battery of further tests to confirm its identification, non-cultural diagnostic methods are often the only option. All non-cultural methods of direct pathogen identification have limits, as discussed in the chapters devoted to individual pathogens. Information on the diagnostic procedure and its performance (sensitivity, specificity, lower detection limit, positive and negative predictive value), limitations, potential errors, disturbances, interference, and cross-reactions, availability of quality control procedures and known reference values, and sample quality should all be taken into account when interpreting diagnostic test results. When dealing with a rare infectious condition, it might be difficult to get credible information on the subject. The aforementioned rule of thumb certainly also applies to culturally dependent methods (Petti et al. 2006).

Cultural techniques are still desired because of some processes, such as the assessment of antimicrobial resistance patterns and numerous typing methodologies discussed in the pathogen-specific chapters. Therefore, even in low-resource situations, there must be BSL-3 reference labs.

Point-of-care molecular diagnostic technologies are often the technique of choice in resource-limited settings without highly established laboratory infrastructure. Some examples of simple point-of-care solutions include the PCR-based GenXpert system (Cepheid, Sunnyvale, CA, USA), the loop-mediated amplification (LAMP)-based Genie II device (Amplex, Gießen, Germany), and the Cobas Liat System (Roche, Basel, Switzerland). For completely automated molecular diagnostic instruments, the manufacturer often defines the number of quality control methods, which should typically include extraction and inhibitory control reactions for molecular diagnostic procedures. To save time and money, fully-automated, closed systems are debating whether or not they may deviate from the stringent rules for molecular laboratories (Porrás et al. 2015).

17. PREVENTION IN CANCER PATIENT

Immuno-compromised cancer patients are vulnerable to opportunistic and healthcare-associated infections. A solid infection prevention program may drastically reduce the risk of infection.
A scientist for the National Park Service (NPS) contracted pneumonic plague after an unprotected encounter with a mountain lion in 2007 and later died. This event triggered an evaluation of staff who work with animals and raised awareness of the risk of contracting a zoonotic illness during employment (Curtis et al. 2018). They surveyed NPS biologists and other wildlife workers across the country online from April to June of 2009 to determine the following:
1) Exposures to zoonotic diseases that may have occurred at work in the previous 12 months
2) Protective practices including the use of PPE
3) Barriers and facilitators to PPE use
The effectiveness of various preventative measures was evaluated and compared to demographic and occupational variables. A total of 238 NPS staff members from 131 parks around the US participated in the survey. There were 71% biologists and technicians, 16% natural resource experts and managers, and 13% people with other occupations. Most respondents only had casual contact with animals, doing things like handling live animals (39%), sick animals (43%), dead animals (46%), or extracting blood (42%), once or twice a year at most. Gloves and proper hand washing were mentioned most often as preventative measures (Sulaiman et al. 2020). Ninety-two percent of respondents agreed that having PPE stocked and easily accessible would promote PPE usage, and ninety-one percent said that having particular PPE kits for use during necropsies and in distant field locations would simplify PPE use. Responses that included reading or reviewing "NPS safe work practices for employees handling wildlife" with a supervisor, including zoonotic disease safety or PPE use in employee performance appraisal plans, or conducting a job hazard analysis for handling wildlife were significantly more likely to have a high summary protective measure score. Ninety people (38%) said they have been trained on how to identify and prevent zoonotic diseases. Our researcher lends credence to the idea that workplace interventions might raise wildlife professionals' awareness of zoonotic diseases and encourage them to adopt preventative practices (Mathews et al. 2021).

18. VACCINATION

Numerous illnesses with high fatality rates and the potential to produce epidemics and pandemics are thought to have evolved in and transmitted to humans from animals (i.e., zoonosis). In addition to affecting cattle output and food security, zoonotic infections are responsible for an estimated 2.7 million human fatalities and 2.5 billion human illnesses per year. By mid-2021, the zoonotic SARS-CoV-2 pandemic, which began in 2020, has already resulted in approximately 4.4 million human fatalities throughout the world (Ronca et al. 2021).

The development of vaccines is among the 20th century's greatest contributions to public health. Vaccination has a long history of success in preventing, controlling, and even eradicating disease, from Edward Jenner's use of cowpox (Variolae) to protect against smallpox. In the 18th century to Pasteur's discovery of how to inactivate the rabies virus to save human lives through vaccination to the urgent need to rapidly create effective vaccines during the explosive SARS-CoV-2 pandemic. Immunization programs for animals have been used to combat zoonotic illnesses by protecting both domestic animals and people from the spread of disease by immunization of wild animals. There is a significant potential research horizon associated with the development of new and better vaccinations to prevent the spread of difficult or developing zoonotic diseases (Monath 2013).

Animal vaccinations have been used for decades for several zoonotic infections. These vaccinations are very cost-effective when administered as part of comprehensive preventative programs, and they have the potential to save lives, boost animal health, and strengthen food and economic security (Wallace et al. 2017).

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