A One-health Approach to Combat Common Pet-associated Fungal Zoonosis

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ABSTRACT

Fungal zoonosis is an infectious disease that can spread from animals to humans. Most of the emerging and re-emerging infections caused by zoonosis. These can be transmitted directly or indirectly by fungi and can pose a serious threat to the world. The emerging infections are those that affect a population within a geographic area for the first time. In addition to posing a serious hazard to society, fungi can spread by sapronotic and zoonotic transmission. According to epidemiological studies, there is a rise in fungal infections in domestic animals. The most emerging cause of this rise in infections is climate change i.e., the fluctuation in temperature, humidity, change in human lifestyle, ecological disruptions and weak immune system. Exposure of zoonotic infection by direct interaction with pets, livestock animals, pet handler and importers. Transmission either directly via direct contact with secretions and excretions of animals, aerosol, faeco-oral route, skin abrasions, cuts and scratches. Fungi such as Dermatophytes, Aspergillus, Cryptococcus, Histoplasma can spread among pets and humans, leading to various diseases and infections such as Dermatophytosis, Histoplasmosis, Cryptococococsis, Paracoccidioimycosis and Aspergillosis. To properly address this issue a One Health strategy that emphasizes the connection of animal, human and environmental health is necessary. In developing countries, education and awareness are particularly necessary where the people lack even the most basic knowledge of numerous issues. In order to mitigate the impact of fungal zoonosis education, better veterinary procedures, cooperative research efforts are essential. By adopting a One Health approach, we can protect the health of both humans and animals.

Keywords: Fungal zoonosis, Dermatophytes, Aspergillosis, Histoplasmosis, Cryptococcosis, Paracoccidioimycosis

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1. INTRODUCTION

An infectious disease that can transmit from animals to humans, is known as zoonosis. A bacterium, virus, fungus, or protozoon parasite can cause it. These infections are transmitted directly or indirectly and become a threat globally. Most of the animals act as reservoirs of the infectious agent and then transmit this infection to humans or other animals. An infected host can also transfer the population's causative agent (Karesh et al. 2012). Most of the emerging and re-emerging infections are caused by zoonosis due to the close contact of animals and humans (Cutler et al. 2010). The infections appearing and affecting a population within a geographical location for the first time are called emerging infections. The infections that once were a global health concern but then declined notably and rise again in a particular geographical area or population called re-emerging infectious diseases. Climate change, import/export, changes in human lifestyle, and ecological disturbances are some of the top reasons behind the re-emergence of infectious diseases. Fungal infections are also a critical threat to society and can be transmitted by zoonotic and sapronotic transmission (Akritidis 2011). The most prevalent fungal infection groups are dermatophytosis, histoplasmosis, and sporotrichosis. Some of the fungal diseases lacked attention in world public health efforts, so having fewer strategies to treat these diseases (Barros et al. 2011; Moretti et al. 2013).

2. FUNGAL ZOONOSIS AND ONE HEALTH

Since fungus zoonosis is a complex and linked health problem based on interactions between animals, people, and the environment, it needs to be prevented on a global scale. The "One Health" method involves working with researchers, policymakers, and leaders locally, nationally, and internationally to enhance the health conditions of people, animals, and the environment. It is an effective approach to organize all stakeholders that can provide benefits to health sectors and arrange all government agencies (Erkyihun and Alemayehu 2022).

Epidemiological studies show an increase in fungal infection in domestic animals. The most emerging cause of this rise in infections is climate change i.e., the fluctuation in temperature and humidity. A rise is seen in the transmission from pet animals to humans. The expected reason for this is the change in human behaviour towards animals. Animals and humans are always living side by side, depending upon each other socially and economically but in recent years there is a rise in the trend of keeping animals as pets at house. There develops a close relationship between a pet and its owner hence close skin contact can easily transfer the fungal infection to humans (Vinke et al. 2020). Another alarming reason for this increase is immunity weakness. The drastic change in the immunity response is seen in the COVID-19 pandemic. The reason for this is still not certain and more research is needed to find the cause and effect of this issue (Azkur et al. 2020).

Pet-associated fungal zoonosis is a growing concern in public health due to its impact on both human and animal populations. Fungi such as *Dermatophytes, Aspergillus*, and *Cryptococcus* can spread among pets and humans, leading to various diseases and infections. A One Health strategy, which recognizes the interdependence of human, animal, and environmental health, is essential to effectively combat this issue.

3. ONE HEALTH APPROACH

The One Health philosophy acknowledges the interconnectedness and need to treat human, animal, and ecosystem health as one unit. By applying this approach to pet-associated fungal zoonosis, we can better understand the complex interactions that lead to the transmission and spread of fungal pathogens. It provides a framework for collaboration and integration of efforts between human and veterinary

medicine, microbiology, public health, environmental science, and other related fields. However, in low- and middle-income countries (LMICs) one health approach received little attention while persistence and emergence of zoonosis poorly understood (Gebreyes et al. 2014).

One health is a multifunctional approach that has an objective to provide ideal health conditions by recognising the connection between environment, humans, animals and plants at global, international, national and local levels. This integrated approach motivates different sectors and even communities to work together to solve the issue of environment and public health threats. It is a system to mitigate and prevent the threats to health and ecosystem (Erkyihun and Alemayehu 2022). The main objective of this approach is to act against climate change, provides clean water, energy, air, healthy and nutritious food. One health approach can enforce different sectors and communities working together to implement policies and legislations for the improvement of public health conditions (Kaswa et al. 2023).

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The concept of one health strategy was given by Rudolf Virchow (1821-1902) in 19th century and then this idea grew globally in 21st century to prevent epidemic diseases and maintained the environmental integrity by collaborating all the departments related to health, food and environment to make new policies and laws for the healthy life of the society (Monath et al. 2010). World bank, United Nations system influenza coordinator, World Organization of animal health (OIE), United Nations Food and agriculture health (FAO) and United Nations Children Fund collaborate and worked on a strategic framework “Contributing One World, One Health”, to reduce the threat of infectious diseases at humans, animals and environment levels in 2008. World Medical Association (WMA) contributing this concept by educating veterinary professionals and in medical schools. The World Medical Association (WMA) and World Veterinary Association (WVA) recommended interdisciplinary collaboration between veterinary professionals and medical personnel to improve the health of both humans and animals at the Global Conference on One Health in 2015, which expanded the one health platform (Erkyihun et al., 2021; Buttigieg 2015).

4. IMPORTANCE OF ONE HEALTH APPROACH

Humans and animals share a common ecosystem so the drug resistant microbes can easily transmit from animal to humans and human to humans by close contact with them and the use of contaminated food. We can prevent the humans from most of the zoonotic diseases like rabies, brucellosis and anthrax by controlling the animals as they are causative agents. Antimicrobial resistance (AMR), environmental pollution, climate change due to anthropogenic activities (emission of greenhouse gases i.e., carbon dioxide, and methane by vehicles and industries) and the destruction of ecosystem are the main problems in the society that can be handle by the collaboration of all departments to eradicate and control these issues. Therefore, a well-coordinated approach to health in the human, animal, and environmental sectors is essential. (Day et al., 2012)

Through one health, collaboration and coordination improve disease investigation, stakeholder communication, diagnostic laboratory systems, and the network for early response and zoonosis detection. This strategy is useful in the prevention of zoonotic diseases by ensuring the collaborative work of all the public health departments. One Health approach deals with common health problems such as zoonosis, antimicrobial resistance (AMR) and food safety at the global level by collaboration, coordination and communication between the health-related departments (Garcia et al. 2004). Anyone can contribute

by promoting and implementing the One Health policies in Human-Animal-Environment health especially the professionals in veterinary and medical sectors can contribute by applying it in their regular practice (Erkyihun et al., 2021).

5. PET ASSOCIATED FUNGAL ZOONOTIC DISEASES

Zoonoses is considered as one of the major public health hazards worldwide, which lead to high mortality in recent times where infectious pathogen not only act as the main source of disease transfer from animal to humans but also as carrier for those pathogens' natural environment (Toma et al. 1999). Inappropriate public health policies mostly in underdeveloped and often in developed countries may result in reoccurrence and emergence of such zoonotic infections globally (Akritidis 2011). There is massive rise in population due to which increases in the food demand and more commercialization resulted in decrease invasion of wildlife habitats and more interaction between humans and animals become the leading cause of spread of different diseases (Satterthwaite et al. 2010). Moreover, exposure of zoonotic infection by direct interaction with pets, livestock animals and indirect connection with pet industry having animal breeders, pet handler, importer and pet distributor and people in close vicinity with animals may act as major infection source (Otero-Abad and Torgerson 2013).

Pets can serve as one of the most important risk factors associated with zoonotic infections, as infection can spread by direct contact with household and indirectly by general public interaction, where majority of people are unaware of zoonotic aspect of these pets especially in developed countries where pets may become important part and parcel of almost every home. There are various routes for transmission either directly via direct contact with secretions and excretions of animals, aerosol, faeco-oral route, skin abrasions, cuts and scratches through which people may develop pet related infections (Mani et al. 2009). A lt of work has been done on pet associated infection caused by bacteria, virus, and parasites but less research done on the fungal zoonotic infection which particularly associated with pets. Globally there are different animals and birds which can kept as pet like cat, dog, guinea pig, rodents, mice, fish etc. (Badyal and Desai 2014).

According to reports there is concept of ecological fitting which shows animal-pathogen interaction between infectious agent (fungi) and its host, where pathogen may adopt different strategies to multiply, colonize and complete its lifespan inside host (mammals) and disturb its immune system. If got a chance it releases and effect the surrounding environment as well (Wolfe et al. 2012).

Fungal diseases termed as silent killer due to its high mortality rate, causing 1.5 million deaths annually without showing signs and symptoms. These fungal infections can be cured but unfortunately very less research has been done in this field and most of these fungi responsible to boost up or increase fatality rate when combined with some other infections like respiratory problems(asthma), organ transplantation, AIDS and cancer (Toland et al., 2020). From last few decades' different epidemiological studies showed the strong connection and increase percentage of different fungal infections particularly associated with domestic and wild animals, but less data available regarding pet association with fungal groups (Wong et al. 2007). Some of important pet associated fungal zoonotic diseases are Dermatphytosis, Basidiobolomycosis, Histoplasmosis, Sporothricosis and Cryptococcosis (Friberg 2021).

5.1. DERMATOPHYTOSIS

Dermatophytosis, also known as ringworm or tinea, is a pet-associated fungal disease of the skin and hair which usually affect the keratinized superficial tissues of human (Fig. 1 2 and 3) usually caused by three important genera i.e., Microsporum, Trichophyton and Epidermophyton. Dermatophytosis is considered to be the most common infection of human skin transferred from pets (Hay, Johns et al. 2014). Regarding

animals, dermatophytosis get more attention due to its zoonotic aspect in dogs (*Trichophyton mentagrophytes*) along with domestic cats (*Microsporum canis*) which is responsible for its spread in humans directly and indirectly by farm workers (Moriello et al., 2017).
Cats may caught *M. canis* infection by staying inside as well as from outside (*A. vanbreuseghemii*) by interaction with hunters. So, there is a chance of transmission of such dermatophytes from soil or rodent during hunting (Drouot et al. 2009). The route of transmission is through the interaction of hair and scales, fungal arthrospores with formites in the infectious environment, and the host natural immune system plays a key role in avoiding dematophtic attack, as well as acting as a predisposing factor for host infection if it is accompanied by ectoparasites. The incidence of dermatophytosis increase due to rapid demand and placement of dog and cat as pets. Dermatophytosis particularly by *M. canis* is contagious and fatal disease which may serve as the main cause of nosocomial infections (Drusin et al. 2000). Table 1 enlisted common dermatophytes species along with the disease it causes and ecology (Bouchara et al. 2017).

5.2. SPOROTRICHOSIS

Sporotrichosis is one of the very important emerging zoonotic disease of the recent times causing severe health problems globally (Etchecopaz et al. 2021). In last two decades the incidence of sporotrichosis rise

Table 1: Common dermatophytes species, diseases and ecology

Species	Diseases	Ecology
Microsporum audouinii	Tinea capitis, mild inflammation	anthropophilic
Microsporum canis	Tinea capitis, severe inflammation	Zoophilic
Trichophyton tonsurans	Tinea. capitis, mild inflammation	Anthropophilic
Trichophyton mentagrophytes	Tinea pedis, tinea manum, tinea unguim, tinea barbae	anthropophilic and zoophilic strains
Trichophyton rubrum	Tinea pedis, tinea manum, tinea unguim, tinea barbae	Anthropophilic
Epidermophyton floccosum	tinea cruris, tinea pedis tinea manum	Anthropophilic

up from few hundred to 10,000 annually. The main culprit of this endemic was *Sporothrix (S.) brasiliensis* and *Sporothrix (S.) sckenckii*. According to study conducted in Brazil which showed the reason behind survival of *S. brasiliensis* in cats was due to structure modification and its survival at high temperature (Bongomin 2017). During cat fights, this fungus can transfer to other cat and humans as well by scratches and cuts (Inokuma 2010). *S. brasiliensis* is a contagious species for which cat act as the primary reservoir, transfering it to dogs and rats as well. The rapid spread of *S. sckenckii* was observed in adjacent states and to date no effective treatment is available. Previous research found that cats, together with dogs, rodents, and squirrels, were mostly responsible for zoonotic spread. Inhalation of conidial spores results in zoonotic transmission to humans (Toriello 2021).
There is evidence of transferring *Sporothrix spp.* through the respiratory droplets of cats. The transmission occurs by the sneezing of infected cat that expel the respiratory droplets having infectious microbes. Physicians should aware of this new transmitting route while treating the cases of *Sporothrix spp.* in humans (Rodrigues et al. 2022). The typical primary lesion of sporotrichosis shown in Fig. 4.

5.3. HISTOPLASMOSIS

Histoplasmosis, also termed as cave sickness, emerging as the serious zoonotic fungal disease responsible for high infection rate up to 5,00,000 people suffer from severe illness and if remain untreated lead to 25,000 deaths annually. Its prevalence increases rapidly to the Caribbean, Southeastern Asia and South and Central America (Almeida et al. 2019). The *Histoplasma (H.) capsulatum* is the etiological agent, firstly

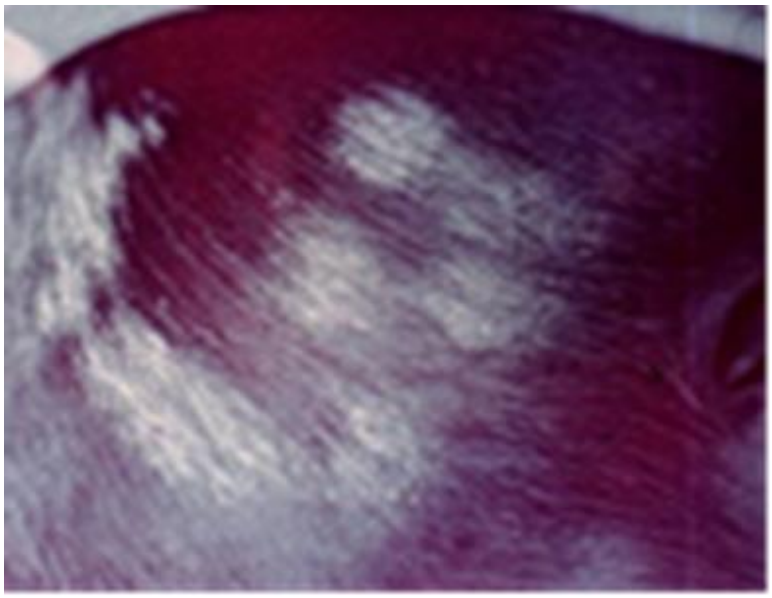

Fig. 1: Tinea capitis under Wood's Light

Fig. 2: Lesions of Tinea barbae

Fig. 3: Lesions of Tinea pedis

Fig. 4: Primary lesion of sporotrichosis

detected in Mexico later on accompanied by great genetic diversity having various virulent factors (Dias et al. 2019). *H. capsulatum* may survive in faecal material of bats and birds and soil of that area encroached with faeces (Antinori 2014). Regarding regional distribution, infected bats travelled great distances and disseminated the disease (Overgaauw et al. 2020). Different recreational activities at wildlife habitats like caving, hiking, bat and bird fighting may become the main culprit behind transfer of histoplasmosis (Diaz 2018). The aerosol transmission of histoplasmosis is done by inhalation of airborne conidia. More incidence is observed in pregnant women and immunocompromised individuals but it remain asymptomatic in immunocompetent persons. Histoplasmosis symptoms can range from being asymptomatic in immunocompetent patients to being lethal in those with impaired immune systems (Benedict et al. 2020).

5.4. CRYPTOCOCCOSIS

Cryptococcosis is recognized as the notorious, contagious and deadly zoonotic fungal disease. This infectious fungus can be fatal without showing any abnormalities in immune system causing more than 1 million deaths annually (Bongomin et al., 2017). Cryptococcosis, caused by *Cryptococcus (C.) neoformans,* is responsible for meningoencephalitis in HIV patients and *Cryptococcus (C.) gattii* may be asymptomatic and cause pulmonary infections in immunocompromised patients (Gushiken et al. 2021). The *Cryptococcus spp.* can be isolated from bird's waste materials such as pigeon or chicken droppings and from soil contaminated with birds' droppings. Some serotypes of fungi were isolated from eucalyptus trees. This fungus usually accompanied each other forming complexes and attack the respiratory system of mammals and farm animals and their companions (dogs and cat) resulting in various outbreaks (Refai 2017).

5.5. BASIDIOBOLOMYCOSIS

Basidiobolomycosis is rare but emerging zoonotic subcutaneous fungal disease which occur due to *Basidiobolus (B.) ranarum* present in decaying plant material, foodstuff, damage leaves and infected soil in the surrounding area (Shreef et al. 2017). Its presence can be observed in the GI tract of amphibians, reptiles, fish and mammals (dog, bat, humans) and in faecal material of kangaroos (El-Shabrawi and Kamal 2011). The fungus is more prevalent in Asia, Africa, South America and Europe and spread by inhaling in

area carrying plant decaying material. It can also be transmitted as a result of traumatic injury during implants. This fungal spores can enter in the body by cut/abrasion in skin and gradually resulted in lumpy growth under the skin, legs and arms. If remain untreated, it transfer to deeper tissues of vital organs like brain leading to death in severe cases. The ingestion of contaminated soil can also transfer and spread the disease (Ageel et al. 2017).

6. POTENTIAL ZOONOTIC FUNGAL DISEASES TRANSMITTED TO HUMANS

6.1. PARACOCCIDIOIDOMYCOSIS (PCM)

PCM is an airborne zoonotic fungal infection caused by *Paracoccidioides brasiliensis* resulted in acute to chronic illness. It is grown in the soil and is commonly found in Brazil, Latin America and Columbia. There are number of factors like human movement to different places, environmental and agriculture modifications, weather changes and expansion in land that may contribute to the spread of PCM. The PCM, which is common in dogs, cats, and other domestic and wild animal by inhaling its conidial spore in the surrounding environment and penetrates in humans and animals through the cutaneous and subcutaneous skin barriers. PCM may also distributed through residential and commercial dwelling areas (Martinez 2015)

6.2. PENICILLOSIS

Penicillosis is an emerging zoonotic fungal disease prevalent in south –East Asia and isolated from liver of bamboo rat. *Talaromyces (Penicillium) marneffei* is causative agent responsible for human infection, causing outbreaks in tropical areas. Dogs, acting as reservoir, are responsible for transmission of this fungus to humans (Hu et al. 2013), Furthermore, the Penicillosis marked as major opportunistic infection which is associated with HIV and AIDS resulted in severe complication. Genetic analysis confirmed the presence of same type of pathogen in rat as in humans which showed its zoonotic relatedness regarding fungal infection (Cao et al. 2011).

The close interaction of infected animals harboring different infectious pathogen may become the leading cause of public health hazard. Pet animals with special reference to dogs and cats serve as primary vector and more prone to transmit such infectious fungi to humans and cause sever life threating fungal infection in humans and animals (Toland et al., 2020).

7. PREVENTION AND CONTROL STRATEGIES

Prevention and control strategies have a long-lasting impact on the spread of fungal infection, its pathogenicity, and transmission from animal to humans. It helps in developing new trends in veterinary sciences as well as in human medical centres. This also provides awareness and education to general public in order to reduce the risk of developing the fungal infections in pet animals and becoming the emerging and re-emerging zoonoses (Rahman et al. 2020).

7.1. ENHANCED SURVEILLANCE SYSTEMS

Collaboration between human and veterinary healthcare providers is essential to establish effective surveillance systems. This would involve monitoring and reporting cases of pet-associated fungal zoonosis to track the prevalence, identify sources of infection, and implement appropriate preventive measures.

The World Medical and Veterinary association signed an agreement to improve the public health conditions by controlling zoonosis such as rabies and AMR (Erkyihun and Alemayehu 2022).
Pet owners and workers of pet shops should aware of causes, symptoms and required medical aid for a fungal infection in the pets. The knowledge of causative agent will help in prevention of infection by eliminating them before it causing the disease in animals. The information of symptoms can benefit to identify the infection on time and to get medical assistance before it become threatening to animal and transferred to humans. Owners and workers should know the implementation of surveillance and monitoring management system. In it not just include the preventive measures but also include the monitoring of all the activities, behaviour, preventive measures and treatments (Garcia et al., 2004).

7.2. EDUCATION AND AWARENESS

In order to prevent and control fungal zoonotic illnesses, it is essential to raise awareness among pet owners, medical experts, and the public. Educational campaigns should focus on proper hygiene practices, early detection of symptoms, and the importance of seeking timely veterinary and medical care. Emergency preparedness platforms must be generated to prioritize the disease risk assessment, simulation exercise and contingency planning (Wolfe et al., 2012).
Education and awareness are particularly necessary in the underdeveloped countries where it is lacking and people do not even have basic knowledge about many serious issues. In underdeveloped countries, there is no trend towards pet ownership, and only a tiny percentage of people maintain pets as pets. Because of this, they lack the fundamental information needed to properly care for feed, and maintain pets. This lack of knowledge leads to development of diseases specifically skin diseases, which include fungal infections in pets and their transmission from the pet animals to humans (Buttigieg , 2015).

7.3. IMPROVED VETERINARY PRACTICES

Implementing rigorous infection control measures in veterinary clinics and animal shelters is crucial. This includes routine screening of pets, isolating infected animals, practicing strict hygiene protocols, and appropriate treatment of infected pets to prevent further transmission. Laboratories are important to detect the pathogens so it's important to increase capacity and integration between them so that laboratories can share protocols and understand the outbreak of a zoonotic disease (Dias et al. 2019).
To improve the veterinary practices, a credible practice called clinical audit is used. Clinical audits done by systematically reviewing the current practices of treatments and handling the patient and bring improvement in the process. By implementing clinical audits in the veterinary literature will bring sustainable improvement in treating and handing of pet animals. In addition to this a pain scale must be implemented in veterinary clinics to assess the severity of pain in the pet animals specially dogs and cats (Rose and Pang 2021).
A mobile veterinary service is also helpful to provide the medical aid on the spot in emergency cases. This will also provide aid to the owners and workers of pets to get medical assistance for their animal on time (Bennett et al. 2019).

7.4. ENVIRONMENTAL MANAGEMENT

The transmission of fungal diseases is significantly influence by environmental conditions. In particular in pet habitats and animal housing facilities, proper waste management, ventilation, and routine disinfection can assist lessen contamination and fungal growth. To stop and manage zoonotic disease outbreaks, a skilled workforce of public health, wildlife, environmental, and domestic animal professionals must be

form on a global, regional, and local level. It should be back by one-health policies (Rocque et al. 2019). Environmental conditions such as temperature and humidity have a direct relation with the fungal growth and hence effect the spread of fungal diseases. Because of manmade activity, the climate is changing dramatically. The rise in greenhouse gases like carbon dioxide, nitrous oxide, and methane has an effect on everything from temperature and humidity to water and light quality.

Temperature and humidity variations, in particular, have an impact on the pathogenicity, survival, and life cycle of fungi. Management and maintenance of these environmental conditions in the pet-keeping areas may help in the reduction of fungal infections in pet animals and ultimately reduce the chance of zoonoses in humans. In this regard, it is important to keep pet animals' fur dry, especially those with long hair, such as some types of cats and dogs. Maintaining the temperature to optimum may help in the prevention of fungal infections (Ageel et al., 2017).

7.5. COLLABORATIVE RESEARCH

Research efforts should focus on studying the epidemiology, pathogenesis, and transmission dynamics of pet-associated fungal zoonosis. This interdisciplinary research would aid in the development of new diagnostic tools, effective treatment strategies, and the identification of potential reservoirs and vectors involved in the transmission. A data sharing platform can be created between all relevant organizations for timely integration and to understand the burden of diseases in the society (Hay et al., 2014).

Research provides benefits to researchers, medical practitioners, and to public in educating them about the health of pet animals and its direct and indirect link to the health of people related to these pet animals. It provides the awareness to the owners of pet animals about the importance of taking medical aid on time. Collaborative research is beneficial especially to the underdeveloped countries as it is economically helpful and provide much needed instructions to the people of these areas (Hosey and Melfi 2014).

8. CONCLUSION

Pet-associated fungal zoonosis poses a significant threat to both human and animal health as the health of pet is linked to the health of the people related to them. Embracing the One Health approach is crucial in tackling this issue comprehensively. The close interaction of infected animals harboring different infectious pathogen may become the leading cause of public health hazard. Pet animals with special reference to dogs and cats serve as primary vector and more prone to transmit such infectious fungi to humans and cause severe life threating fungal infection in humans and animals. By understanding the interconnectedness between humans, animals, and the environment, we can implement effective preventive and control strategies. Enhanced surveillance systems, education and awareness campaigns, improved veterinary practices, environmental management, and collaborative research efforts are key components in combating pet-associated fungal zoonosis. By adopting a One Health approach, we can protect the health of both humans and animals and reduce the burden of fungal zoonotic diseases in our communities.

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