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Public Health Threats from Pet Bird Zoonoses

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The very high exotic or genetic value made pet birds, likecanaries, parakeets, and parrots a choice for trade across countries and continents, and the capability of these birds to act aspotential carriers or transmitters of zoonotic diseases contributes a significant threat to humans. Birds are characterized and known for their susceptibility, transmission, and maintenance of pathogens that are zoonotic to humans. Some of the zoonotic diseases they spread, such as highly pathogenic avian influenza (HPAI), salmonellosis, and chlamydophilosishave a significant impact on human health and these things make this issue a one health concern. Zoonotic diseases among birds areclassified as bacterial, viral, fungal, and of parasitic origin. The intensity with which they affect humans varies according to their pathogenicity and virulence. The awareness of pet bird zoonosesis of prime importance while trading or domesticating the bird, which will help to understand their potential fordiseases and install preventive measures accordingly. This review

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paper aims to educate readers about the risks faced by bird owners and the public by describing several instances of bird-human disease transmission and the characteristicsymptoms of those diseases.

Keywords: Pet birds; zoonosis; chlamydophilosis; salmonellosis; avian influenza; new castle disease.

1. INTRODUCTION

Except for poultry, pet birds are any species of birds kept as a pet. They primarily belong to the Passeriformes and Psittaciformes groups. Songbirds are a common name for Passeriformes (e.g., canaries, finches, sparrows, etc.).Columbiformes include pigeons and doves, and Psittaciformes include parrots, parakeets, budgerigars, love birds, etc. Zoonoses are infectious diseasesthat can be transmitted from animals or birds to humans and vice versa. Birds have several epidemiological rolesin the transmission and maintenance of zoonoses, including their high susceptibility to pathogens causing hazards to humans (Highly pathogenic avian influenza virus, West Nile virus, and *Chlamydia psittaci*) and their ability to travel long distances, especially in the case of migratory birds. Poultry products (meat, eggs, and their by-products) also lead tofoodborne zoonoses. The close contact between humans and pet birds or urban birds leads to interactions of public health concerns [1,2].

Pet bird zoonosesarean emerging public health issue, especially as pet bird ownership increases day by day, and the proportion of reservoirs of zoonotic diseases increases. Many pet bird owners are often unaware of the risks their pets may cause and, as a result, engage in husbandry and hygiene practices that increase the likelihood of acquiring and developing diseases [3]. The occurrence of zoonoses depends on several factors such asthe duration of exposure, the virulence of the pathogen, pathogenic survival, route of infection and transmission, and vector availability. Human health problems resulting from direct contact with birds are associated with bacterial, viral, fungal, parasitic, and allergenic agents [4,5]. Veterinarians, owners of poultry farms, breeders of ornamental birds, zoo staff, and employees of poultry slaughterhouses are the occupational groups with the highest risk of exposure to birds and their zoonoses. In any case, extra care should be taken when people come into contact with birds, their droppings, or their secretions. In this manner, the detrimental effects of birds on human health can be reduced or altogether avoided [6].

2. MAJOR BACTERIAL ZOONOSES

2.1 Diseases

2.1.1 Chlamydophilosis

Chlamydophilosis is the most dreadful zoonotic bacterial disease. *Chlamydophilapsittaci*, which affects both domestic and pet birds, causes chlamydiosis, also known as parrot fever, ornithosis, or psittacosis. Most often, human cases result from direct contact with infected pet parrot-type birds, particularly cockatiels, parakeets, and conures, or indirectcontact with feces and nasal secretions of infected birds.Through the Nationally Notifiable Diseases Surveillance System, 112 human cases of psittacosis were reported to the Centers for Disease Control and Prevention between 2003 and 2014 [7]. There are seven genotypes of the obligate, intracellular, gram-negative bacterium *Chlamydophila psittaci* (A-F and E/B) [8]. Genotypes can be identified by sequencing the outer membrane protein A (*omp A*) gene, like A in psittacine birds, B in pigeons, C in ducks and geese, D in turkeys, E in pigeons, ducks, and other avian species, and F in parakeets are the genotypes that are assumed to exhibit strict host specificity [9].

An indirect haemagglutination assay used to determine the seroprevalence of *Chlamydia psittaci* in pet birds in Northwest China revealed the survival of *Alauda arvensis* (9.34%), *Carduelis spinus* (12.5%), and *Coccothraustes migratorius* (5.56%). It also revealed that the seroprevalence in adult pet birds (12.4%) was significantly higher than in juveniles (4.83 percent) [10]. The frequency of *Chlamydia psittaci* infection was 19.9% in psittacine birds, and it showed a higher prevalence in pet birds compared tozoo birds in Kunming, Yunnan, China. *Araararauna* revealed aprevalence of up to41.2%. A high prevalence of *C. psittaci* genotype A infection in psittacine birds was revealed by a genotype study, indicating a potential risk to human health [11]. Doxycycline, tetracycline, or enrofloxacin have been used successfully to treat or prevent psittacosis in birds [12,13].

C. psittaci is transmittedfrom bird to bird by blood-sucking ectoparasites like mites, lice, and flies or, less frequently, through wounds or bites, as well as vertical transmission which was recorded through feeding or regurgitation. Parakeets have shown vertical transmission, though the frequency seems to be quite low [14]. There have also been a few isolated cases of person-to-person transmission [15]. Human psittacosis can present with a wide range of clinical symptoms, from asymptomatic infection or a mild non-specific illness to more serious pneumonia [16,17]. A **micro** immunofluorescence (MIF) test to check for an increase in the *C. psittaci* antibody titer is the most frequently used test to confirm psittacosis [18].

Prevention of this disease includes measures such as cages of infected birds that must be thoroughly disinfected because *C. psittaci* resists desiccation for months. In addition to wearing protective clothing and a high-efficiency respirator (N95 rating), handlers of sick birds should also receive medical attention [18]. Effective preventative measures implemented in birds beforethe sale would improve the ability to stop the spread of disease to pet owners and other susceptible avian species [19].

Public health authorities in the city of Dom Pedrito, Rio Grande do Sul State, received a report of a respiratory illness affecting eight members of the same family. During the investigation, it was discovered that the illness began after direct contact with monk parakeets that had died a few days after being bought from illegal trade, leading to the suspicion of psittacosis. Additionally, patients were deemed to have confirmed cases of psittacosis when their clinical condition was compatible with the disease and their lab results were positive for IgG or IgM by MIF [20].

More people should use PCR-based testing in suspected psittacosis cases because it helps with early diagnosis and the start of the proper antibiotic treatment, which lowers morbidities and mortalities [8]. Any bird that exhibits nonspecific signs of illness and is lethargic should be examined by a veterinarian for avian chlamydiosis, especially if the bird has recently been stressed or purchased. The attending veterinarian should follow local and state guidelines regarding case reporting and submit the necessary laboratory specimens to confirm the diagnosis of avian chlamydiosis. They should also inform clients that infected birds should be isolated and treated [18].

Since there is currently no effective vaccine that can provide lifelong immunity, the total eradication of the highly contagious zoonosis known as chlamydiosis appears to be challenging. There is currently no preventative vaccine for both humans and animals, including birds [21].

2.1.2 Salmonellosis

Salmonella is a different zoonotic bacterium that has been linked to suspected human-to-bird transmissions. Certain strains of *Salmonella* Typhimuriumhave been identified as being host-adapted for causing disease in pigeons. Pet birds are most affected by *Salmonella* Pullorumand *Salmonella* Gallinarum, which cause systemic disease [22,23].

All bird species of all ages are susceptible to salmonellosis. Vertical transmission or indirect contact between sick and healthy birds has been documented [24]. After the microorganisms colonize their gastrointestinal tracts, infected birds become carriers and release them into the environment. Serovar*S.* Enteritidis is most frequently isolated from hens, chickens, and humans, whereas *S.* Typhimurium is found in pigeons and waterfowl (ducks and geese). One Falconidaehybrid out of 444 was examined for *Salmonella spp*. tested positive for *S.* Livingstone, with a prevalence of up to 0.23% [3].

Salmonella spp. zoonotic transmission from parakeets kept as a pet to humans has been documented. Families who raise a pet bird have a higher risk of infection in children (under 5 years). A salmonellosis outbreak occurred among elementary school students linked to the dissection of an owl. *Salmonella spp.* transmission between wild birds, pet birds, and people has also been documented in open-air aviaries and kid's zoos. Such aviaries should be designed with particular care [25].

2.1.3 Campylobacteriosis

Campylobacter *spp.* is athermophiliczoonotic bacteriumthat frequently colonizesthe gastrointestinal tractsof avian species' [26]. In terms of the number of outbreaks it causes, campylobacteriosis is the second-most significant zoonosis in the European Union (and the leading zoonosis in terms of the total number

of human cases) [27]. 90% of the strains of *C. jejuni* isolated from humans are similar to those found in birds. Campylobacteriosis may be seasonal that affects people who live in a temperate climate (spring-summer) and the oral route is crucial when birds are the source of the infection [28]. An investigation was conducted to confirm the presence of these microbes in a diverse Italian population of pet birds and caged raptors, where 444 samples of *Salmonella spp.* and 151 samples of thermophilic *Campylobacter spp.* were tested. The findings imply that these microorganisms are sporadic discoveries rather than regular inhabitants of the digestive tracts of pet birds and captive birds of prey [3].

A total of 120 samples of lovebirdfeces were collected from various locations in Shahrekord, Iran, and evaluated for the presence of *Campylobacter* using bacteriological and PCR methods. Of these samples, 1.7% were positive. Isolates of *Campylobac*ter exhibited high levels of antibiotic resistance [29].

The prevalence of *Campylobacter spp.* in pet birds raised in southern Italy has been investigated in which atotal of 13.6%of the cage samples tested positive for *Campylobacter coli* after feces were taken from 88 cages housing pet birds and examined by bacteriological culture and polymerase chain reaction. According to the study, it is possible to isolate *C. coli* from the cages of seemingly healthy pet birds. As a result, these birds should be taken into consideration as potential *C. coli* carriers for both humans and other animals [30].

2.1.4 Mycobacteriosis

Although *Mycobacterium aviumsubsp.avium* is typically the culprit in bird mycobacteriosis, more than ten other mycobacterial species have also been linked to bird infections. *M genavense, M tuberculosis, M bovis, M gordonae, M nonchromogenicum, M fortuitumsubspfortuitum, M aviumsubsphominissuis, M peregrinum, M intermedium, M celatum, M intracellulare, M aviumsubspparatuberculosis, M africanum, and M simiae* are a few of these [31]. *M. genavense* is the primary cause of mycobacteriosis in psittacine birds and the potential for the zoonotic disease should be considered, especially for immunocompromised owners [32]. *M.genavense* is regarded as the primary cause of mycobacteriosis in psittaciform and passeriform birds, and in humans, *M. genavense* is especially pathogenic for young, old, pregnant, and immunocompromised people [33].

Histologic examination of an Amazon parrot with proliferative skin lesions revealed several granulomas and acid-fast bacteria in the skin lesions. and theowners were diagnosed with pulmonary tuberculosis. Through culture, *M. tuberculosis* was discovered, and subtyping by mycobacterial interspersed repetitive units and restriction fragment length polymorphism revealed that the isolates from the owner and their pet bird were the same [34].

The emergence of MDR-*M. avium subsp. avium* is regarded as a threat to the public's health. Domestic birds frequently carry the IS901, *inhA, rpoB, rpsL*, and*trB* genes in emerging MDR-*M. avium subsp. avium*. The *in-vitro* antibacterial activity of azithromycin and clofazimine against *M. avium subsp. avium*is promising [35].

2.2 Transmission of Bacterial Diseases

There are five different ways by which the zoonoses can spread:pathogen transmission via direct or indirect contact; biological and mechanical vectors; through the digestive system; vertebrate and invertebrate organisms serve as hosts for cyclozoonoses, and infected animal organ transplant recipients can contract xenozoonosis [6].

2.2.1 Direct contact

Zoonoses are primarily spread through the housing of pet birds. All of these birds have been kept together in pet stores, increasing the possibility of direct contact. Crowding also puts a lot of stress on the birds, and weak, stressed birds are much more susceptible to infectious diseases [4]. The risk of pathogen transmission from birds purchased for competition and shows may be very high [36]. Animal predators might also be infected.

Pigeon droppings may act as a vehicle for the introduction of moldand pathogenic yeasts into the environment. Pigeon droppings pose a risk of fungi, such as *Cryptococcus neoformans*, spreading to immunocompromised people in attics, dovecotes, and other nearby locations. This fungus can persist for more than two years andwhen droppings turn to dust, inhalation takes place [37]. Weak people may experience severe symptoms. For instance, the most frequent cause of fatal meningitis in individuals with AIDS

is cryptococcosis (AIDS). Therefore, it's important to prevent immune-compromised people from repeatedly coming into contact with pet birds or their droppings [38].

2.2.2 Vector borne

Vectors are another means of zoonoses transmission. Vectorscan be mites, mosquitoes, ticks, etc. The ecology of the vector, which is in turn shaped by its genetic ancestry, environment, and the hosts it feeds on, has a significant impact on the transmission of vector-borne pathogens [39].

2.2.2.1 Mites

The birds' environment is frequently home to mites. *Dermanyssus gallinae* is one of the "red blood mites" that are the most harmful. It is a mite that is frequently connected to wild pigeons. Other bird species, including pet birds, may also contract the disease. Despite *D. gallinae* typically being nocturnal, the effects of infection can be seen during the day [40,41]. It is known that *D. gallinae* can spread several zoonotic pathogenssuch as *C. psittaci* [1].

20 urban outbreaks of red-mite dermatitis were reported to occurred in Southern Italy between 2001 and 2017. Patients were affected by both pet canaries and mites that migrated indoors from abandoned Sinantropic bird nests nearby and became infected in their homes or places of employment [42]. Red mite is crucial in the spread of *Borrelia burgdorferi* and *Coxiella burnetii* [43].

The mite *Ornithonyssussylviarum* is the Northern fowl mite or white poultry mite. It is the worst pest in North American poultry farms and a blood-feeding ectoparasite. *O. sylviarum* was discovered in whopping canaries (32%), estrildid finches (14.3%), budgerigars (4.2%), and love birds (6.2%). These results highlight the necessity of monitoring *O. sylviarum* in Portugal's domestic and wild avifauna [44]. Depression, anemia, and newborn mortalitiesare clinical symptoms of the infestation.

2.2.2.2 Mosquitoes

The *Culexpipiens* complex of mosquitoes is important in the transmission of many pathogens such asWest Nile fever virus [45], St. Louis encephalitis viruses, avian malaria (*Plasmodium* spp.), and filarial worms. Urban and sub-urban temperate and tropical regions are home *to Cx. Pipienspipiens* and *Cx. quinquefasciatus* which are frequently the main disease vectors in these areas. When combined with their mixed feeding habits on birds and mammals (including humans), the *Cx. pipiens* complex mosquitoes' adaptation to human-altered environments resulted in their global distribution and increased the transmission of several avian pathogens to humans [46,47].

2.2.2.3 Ticks

Ticks are regarded as the second-most significant global vector of infectious agents after mosquitoes. They are widely found, but their prevalence is higher in nations with warm andmuggy climates [48]. Most tick species live in habitats like forests, savannahs, grasslands, and scrublands where they can endure long periods before they find a host to feed on [49]. *Ixodidae*, or hard ticks, are significant disease carriers in both humans and animals [50]. Lyme borreliosis and tick-borne encephalitis are becoming more common in several northern European nations, and tick-borne encephalitis is an emerging illness in Norway [51]. Diseases carried by ticks can be spread by birds over great distances and geographic barriers.

3. VIRAL ZOONOTIC DISEASES

3.1 Avian Influenza

Avian influenza A virus (an orthomyxovirus) is a zoonotic pathogen with a natural reservoir entirely in birds. The 8-segmented single-stranded RNA influenza virus genome has a high propensity for in situ recombination [52].

If infected birds are kept together after capture or during quarantine, the AIV infection in psittacine birds can be spread through direct contact. The AIV infection can spread from one continent to another through international trade in exotic birds [25].

Direct contact with infected birds, coming into contact with feces-stained surfaces, and oral or nasal discharge from infected birds are the three main ways of disease transmission. Fever, sore throat, cough, muscle aches, eye infections, pneumonia, and severe respiratory infections are some of the clinical signs [53,54].

Recently, influenza A (H7N9) of avian origin spread to China and infected people severely.

Finches, sparrows, and parakeets helped a human subtype H7N9 isolate replicate, shed high titers via the oropharyngeal route, and exhibited few symptoms of the illness. The study showedthat a human isolate can replicate in and be shed into the environment by such songbirds and parakeets [55].

The potential role of pigeons and doves in the transmission of avian influenza [56] has come to light considering recent reports of the detection of the zoonotic low pathogenic avian influenza H7N9 viruses in healthy pigeons. Only 9/6155 (0.15%) viruses were found in regions that at the time had outbreaks of a notifiable serotype, and only 1.1%of the 6155 columbids sampled tested positive for the virus [57]. In samples from pet birds, swine tissues, human airway and ocular cells, and ferrets, a study showed replication of an H9N2 virus that was isolated from a pet market in Bangladesh. The findings suggested that this virus may spread and be transmitted zoonotically by pet birds [58].

3.2 New Castle Disease

Exotic Newcastle Disease (END) is a virus that infects many species of birds and is extremely contagious. Other caged birds, including psittacine, are also vulnerable to END. The Texas Animal Health Commission reported in 2013 that this disease is widespread throughout the world. Amazon parrot domestication is challenging. Selling a lot of young parrots should raise suspicions that the birds were either brought in illegally or that the seller is buying them. They can shed the virus for more than 400 days [59].

A set of 335 samples was collected from 24 species of exotic unvaccinated caged birds kept in the zoological gardens and bird markets of the Tehran province of Iran for 1.5 years. NDV was detected in three sick pigeons by haemagglutination assay (HA), haemagglutination inhibition (HI), and reverse transcription-polymerase chain reaction (RT-PCR) tests while two of them were identified as virulent types by RT-PCR [60].

Aged 37 days and 4 years, two sick red-headed lovebirds were brought to the Veterinary Research Institute's Department of Avian Diseases and Diagnosis for evaluation. Following inoculation in the allantoic cavity of 10-day-old fertile eggs, NDV was isolated from the lungs, trachea, and intestines. The NDV was identified by HA&HI tests using specific NDV antisera (LaSota strain). The intracerebral pathogenicity index (ICPI) value of 0.9, which indicatedthe isolate is of the lentogenic type, was studied to determine the pathogenicity of the NDV isolate. The mean death time was 96 hours [61].

The export country's certified veterinarian must complete a health certificate within 30 days of departure, and regulations for commercial and pet bird imports must be followed. The health certificate must state that the bird has not received a vaccination against highly pathogenic avian influenza (HPAI), including the H5 and H7 subtypes, may not transit through areas that the Animal and Plant Health Inspection Service (APHIS) considers to be at high risk for HPAI, must have received an NDV vaccination more than 21 days before export with a lentogenic strain or not, and must be free of infection [62].

Clinical symptoms include subconjunctival ecchymoses, watery eyes, swollen eyelids, and conjunctival redness on one or both sides. Although a horizontal route may be used, there haven't been any reports of the infection spreading from person to person up to this point [6]. Preventive measures such as vaccination could reduce clinical symptoms in pet birds, as well as the duration and volume of viral shedding [63].

3.3 West Nile Fever

The West Nile fever virus is amplified in Passeriformes or perching birds. Some members of other orders, such as Strigiformes (owls), Falconiformes (hawks, eagles, and related species), Charadriiformes (shorebirds), and Falconiformes (vultures and related species), may also spread the virus to mosquitoes. Theoretical explanations for how the virus spreads attributed this to migratory birds by contact. Pets carrying zoonotic viruses (Arboviruses) could be introduced into urban areas (e.g., houses) where *Culex* are abundant allowing transmission of the virus to man [64,65].

3.4 Proventricular Dilatation Disease

Psittacine birds kept in captivity are susceptible to the deadly and debilitating proventricular dilatation disease (PDD), which affects a variety of species, including those that are endangered. The PDD in three blue-and-gold macaws (*Araararauna*) in southern Brazil [66]. Along with emaciation, seizures, and other neurologic

changes, the syndrome is linked to gastrointestinal dysfunction, nervous system inflammation, and other changes [34].

3.4.1 Parasitic zoonotic diseases

One of the most widespread zoonotic diseases in the world, toxoplasmosis is brought on by the protozoan parasite *Toxoplasma gondii*, and it can affect a variety of warm-blooded mammals and birds. The genetic characterization of *T.gondii* and the seroprevalence in three species of pet birds in China revealed *T. gondii* infection in pet birds in Gansu province [67]

Based on histopathology, immunohistochemistry, and multilocus DNA typing, a pet peach-faced lovebird (*Agapornis roseicollis*) was found to have the *T.gondii* atypical type II genotype. Pet birds may serve as indicators of the risk of environmental transmission to any intermediate host, even though direct transmission of *T. gondii* from a pet bird to humans is extremely unlikely given the confinement of oocysts to the gastrointestinal tract and tissue cysts to internal organs [68]. By using Sheather's sugar flotation, the overall prevalence of *Cryptosporidium* was found 8.1% (35/434) [69].

3.4.2 Fungal zoonotic diseases

Cryptococcus neoformans is an encapsulated yeast that replicates by budding. Bird species can carry the spores, and bird droppings, particularly pigeon droppings, are a major source of transmission. Additionally, it can be found in bird-dropping-contaminated soil. From these sources, both people and a variety of animals can contract the disease [37].

C. gattii and *C. albidus* have been found in domestic pigeonslivingin a breeding facility with other birds. Under the right lower eyelid, the animal displayed a pinkish, vascularized mass with a gelatinous aspect that was about 2 cm in diameter. During the microbiological examination, *C. gatti, C. albidus*, and both *Cryptococcus* species were isolated from the eyelid mass, the lungs, the liver, the trachea, and the muscle and kidney [70].

Another fungal zoonotic disease spread by pet birds is aspergillosis. The pulmonary symptoms are brought on by airborne transmission [1]. Workers in pet stores who handle infected birds, and their contaminated food and litter are more likely to develop aspergillosis [34].

One of the serious protozoan diseases that affect birds, cryptosporidiosis is spread through contaminated food and water. In birds, cryptosporidiosis results in the development of either a respiratory or a digestive illness, and humans can contract the disease via exposure to the infected droppings [71]. Cryptosporidiosis becomes significant public health and veterinary concern [72]. Among the various *Cryptosporidium* species, *C. meleagridis* had a wider host range and was more easily spread to humans [73].

4. CONCLUSION

Pet bird domestication is increasing exponentially like dogs and cats in this era as an impact of COVID-19 havoc, on the mental well-being of humans. The masked threat that poses among the domestication of pet birds is the risk of dreadful zoonotic diseases, which are less cared for by humans during their domestication. The diseases like cryptosporidiosis, chlamydiosis, salmonellosis, and toxoplasmosis have the potential to cause a fatal outcome. The increase in demand for exotic pet birds also has a greater impact which can lead to pandemic diseases like highly pathogenic avian influenza, occurring during the transportation of birds from different countries and continents. Thus, illegal trading and carelessness regarding zoonotic diseases can create an extremely dangerous situation, which we all have to bear in mind, before dealing with these things. One should be always aware of the potential of exotic pet birds to spread disease among humans and one who is trading the pet birds should take the authorized screening test before transporting the birds and pet owners should be educated regarding the uneventful conditions regarding pet bird domestication.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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