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REVIEW

Zoonotic diseases from birds to humans in Vietnam: possible diseases and their associated risk factors

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Abstract

In recent decades, exceeding 60% of infectious cases in human beings are originated from pathogenic agents related to feral or companion animals. This figure continues to swiftly increase due to excessive exposure between human and contaminated hosts by means of applying unhygienic farming practices throughout society. In Asia countries—renowned for lax regulation towards animal-trading markets—have experienced tremendous outbreaks of zoonotic diseases every year. Meanwhile, various epidemic surges were first reported in the residential area of China—one of the largest distributor of all animal products on the planet. Some noticeable illnesses comprising of A/H5N1 or H7N9—known as avian influenza which transmitted from poultry and also wild birds—have caused inevitable disquiet among inhabitants. Indeed, poultry farming industry in China has witnessed dynamic evolution for the past two decades, both in quantity and degree of output per individual. Together with this pervasive expansion, zoonotic diseases from poultry have incessantly emerged as a latent threat to the surrounding residents in entire Asia and also European countries. Without strict exporting legislation, Vietnam is now facing the serious problem in terms of poultry distribution between the two countries' border. Even though several disease investigations have been conducted by many researchers, the disease epidemiology or transmission methods among people remained blurred and need to be further elucidated. In this paper, our aim is to provide a laconic review of common zoonotic diseases spread in Vietnam, outstanding cases and several factors predisposing to this alarming situation.

Keywords Zoonotic diseases · Birds · Human · Vietnam · Risk factors · Review

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Introduction

Zoonotic diseases are defined by the capacity of mutual transmission between animals and human [1]. It is widely proposed by scientists that around three-fifths of all human maladies are originated from animal species, whereas approximately 75% of recently emerging contagious illnesses are potentially zoonotic derivation [2].

Poultry population is continuing to expand their distribution in order to literally resolve the exponential growth in human consumption. In 2016, the statistics determined that the average supply of chickens worldwide was around 22.70 billion [3]. As the human population registered by nearly 7.5 billion in the year 2016, it could be inferred that for the number of chickens was threefold compared with that of human beings [4]. Therefore, the intermittent occurrence of various avian-related diseases has been announced throughout the entire planet every year [5]. Consequently, there have been accretive demands in assimilating information preceded low-virulent sources of illness as well as highly pathogenic avian zoonotic diseases in recent years. Meanwhile, there are a number of diseases with pathogenic significance such as avian influenza, Newcastle disease, and campylobacteriosis [6]. For those who are owning wild birds, whether as pets or as rearing animals for lucrative purposes, ought to perceive about particular hazards of zoonotic diseases. Prevailing wild birds including canaries, parakeets, or parrots are potential carriers of some illnesses with crucial influence on human health like chlamydiosis, salmonellosis, or even HPAI A/H5N1 [7]. Generally, birds infected with these maladies appear asymptomatic, which may exacerbate the viable consequences in human beings [8]. Individuals with particular health care status such as chronic diseases, immunodeficiency, or gestation may encounter sophisticated complications during disease progression [9].

Vietnam is recognized as a hotspot for emerging new zoonotic diseases, yet limited source of data has been provided. Several information were published to clarify the negative impacts of zoonotic diseases from birds, though additional information is required. From December 2003 to April 2010, the number of Vietnamese citizens identified with avian influenza was the second highest among Asia with 119 substantiated cases, with 50% fatality rate [10]. Despite its relentless circulation by triggering outbreaks in poultry, Vietnamese government had not testified any fatal cases following April 2010 until January 2012 [11]. Nevertheless, four infected cases and two dead patients were reported in early 2012. Prior to July 2012, there were a total of 123 patients of avian influenza, with 61 losses. Since the beginning of 2018 up to now, there have been 9 patients dead because of A/H1N1 influenza in Vietnam [12]. Due to their capricious distribution and high mortality rate, these illnesses are of excessive concerns towards their epidemiology, routes of transmission, or factors predisposing to the occurrence of the pathogenic agents. However, few pieces of research about this topic were conducted in Vietnam despite the tremendous consequences of the diseases on the nation. As the result, more information on mutual interaction between zoonotic infections from birds and several statistic data in Vietnam will be provided in order to assist in clarifying about the current situation.

The possible zoonotic diseases from birds to humans in Vietnam

Bird flu (avian influenza)

Among the viruses classified in the family Orthomyxoviridae, influenza A virus is of major concern for pervasive incidence and fatality in humans [13]. Relatively, the disease formation emerges in relation to two dissimilar protein components. These proteins—hemagglutinin (H) with 18 varieties and neuraminidase (N) with 11 varieties—together give rise to many subtypes of Influenza [14]. Wild birds belonging to family Anatidae including geese, wild ducks, gulls, shorebirds, terns, and swans are natural carriers of most influenza A subtypes [15]. All acknowledged subtypes of influenza A viruses are capable of causing infection in birds, except H17N10 and H18N11, which have only been reported in bats. Unlike other species, birds can be contaminated with all attainable combining of H and N, or an overall of 153 species [16]. Basically, a large proportion of viruses do not induce any kind of disorders in birds, which referred them as “low pathogenic avian influenza” (LPAI) strains. However, some of these LPAI strains are capable of invading poultry’s immunity, which further undergoes mutation to convert into a more virulent form of avian influenza-HPAI virus. At present, widespread epidemics of highly pathogenic viruses have proved H5 or H7 subtypes for major etiology [17]. Therefore, all cases with these two viruses are defined as prominent and require fully investigated from both scientists and societies. Two highly pandemic strains which cause devastating impacts in human have been H5N1 and H7N9 [18]. Despite their similarities in type of viruses, there has been a significant transformation in relation to epidemiology and possible pathogenesis. Since H5N1 first recorded case in Hong Kong in 1997, it was confirmed to re-emerge among Asian countries between 2003 and 2004 [19]. According to the World Health Organization, the world has a total of 608 cases of avian influenza with 359 deaths in 15 countries, reported in September 2012 [20]. In February and March 2013, avian influenza A (H7N9) was first informed as imperative consideration among the society in eastern China [21]. In Vietnam, human infectious incidence with HPAI was in third place globally in the year 2012, at about 50% [22–24]. From 2013 until now, Vietnam has successfully controlled the occurrence of

influenza A/H5N1 with no report of new cases in humans. However, avian influenza outbreaks in poultry were detected in 11 distinct areas including Cao Bang, Bac Ninh, Nam Dinh, Nghe An, Ha Tinh, Dong Nai, Tay Ninh, Can Tho, Bac Lieu, An Giang, and Soc Trang in 2017 [25]. Recently, more than 50 million poultry individuals have been wiped out for HPAI control measure in Vietnam.

Newcastle disease

Newcastle disease virus (NDV) contain isolates which are sorted within the family Paramyxoviridae, specifically as genus *Avulavirus* [26]. This ubiquitous virus consists of the avian paramyxovirus type 1 (APMV-1) serotype, which induces various expressions of diseases ranging from sub-clinical infection to high fatality rate in susceptible hosts. Together with avian influenza, Newcastle disease has covered pervasive impact on poultry medical management [27]. The clinical signs have direct association with the hostility of the strain, distinct species susceptibility and also the predisposition of disease affecting the respiratory, GI tract, or central nervous system [23]. Despite many reports of Newcastle disease in poultry, merely six records in literature confirmed its incidence in human beings [28]. Among these reports, only two disclosed the recovery of the disease. One of the most observable clinical signs in human is conjunctivitis, which occurs throughout 24 h of NDV infection to the ocular surface [29]. Newcastle disease in chickens was first detected in Java island, Indonesia, and in Newcastle upon Tyne—a city in North East England in the year 1926 [30]. Until 1943, the first documented illness of Newcastle disease in human happened due to imprudent handle of a contaminated sample inside a laboratory in Malaysia [31]. Allantoic fluid contained both Newcastle virus and influenza B virus was accidentally squirted into the eye [32]. The patient rapidly developed severe symptoms including mucopurulent conjunctivitis, headache, chills, and malaise within 24 h. The infection was then recovered and local status improved after 1 week. So far, no zoonotic cases of Newcastle disease in human has been reported in Vietnam.

Salmonellosis

Salmonella is a genus of rod-shaped (bacillus) Gram-negative bacteria belonging to the Enterobacteriaceae family. It is a pervasive bacteria with multiple strains which results in an acclaimed pattern of food poisoning globally [33]. With the excessive number of more than 2500 dissimilar serotypes of *Salmonella*, these bacteria are known to expand their distribution in various environmental conditions and species infection [34]. Diseases mostly occur in the alimentary tract of avian, reptiles, and amphibians as well as mammals. Despite their commonplace distribution, *Salmonella*-derived infective disease is scarce due to their low pathogenicity [34]. Ordinary clinical indications in all species comprise watery diarrhea, emesis, and slight febrile [35]. Other detectable signs may be dehydration, physical deficiency, septicemia, and headache. In human, around 15 serotypes of *Salmonella* are causative agents for the most cases, with relatively short incubation period of 12 to 72 h. According to many research, Salmonellosis is typically acquired by fecal-oral route, remarkably via inadequate cooking process of food previously contaminated with fecal matter. Basically, salmonellosis is mild infection and self-recovery without the utilization of any antibiotics or supportive treatment [36]. Patients will be ameliorated within a few days comforting and drinking water more frequently. On December 4, 2018, 25 patients from six states in the USA (including Maryland, Massachusetts, New York, Ohio, Pennsylvania, Virginia) were informed with the outbreak strain of Salmonella. Illnesses happened among people of different ages, from infants to adults, with a median age of 16. Approximately 50% of infected people were female. Among 22 patients with data available, 11 people were hospitalized, including one fatal case testified in New York City [37]. As 14 people were interviewed about their dietary consumption and potential exposures in the previous week, all confirmed eating poultry-related foodstuffs. In Vietnam, there have been many cases of mass poisoning due to Salmonellosis, nearly 250 people in Dong Hoi were hospitalized on October 2015 because of contaminated bread with meat and egg [38]. According to Ho Chi Minh City Preventive Medicine Center, there were 43 cases of Salmonellosis in 2016 [39]. Meanwhile, three typhoid patients were recorded within the first 3 months of 2017. The study on Salmonellosis was conducted by a clinical research group at Oxford University (OUCRU) for more than 1 year in Ha Noi and Ho Chi Minh City [40]. Among 117 samples of poultry, swine, and cattle, 80/117 samples (more than 68%) were contaminated with Salmonella. In Ho Chi Minh City, the percentage of infected samples was 71.8% (poultry); 70.7% (swine); and 62.2% (cattle).

Mycobacteriosis (avian tuberculosis)

Avian tuberculosis is described as a daunting problem affecting various categories of animal species, ranging from domestic, exotic, and even feral avian and mammals [41]. The illness occurs mostly in relation to *Mycobacterium avium*, which is considered ubiquitous and a significant source of poultry infection. Other atypical *Mycobacterium* strains have been scientifically proven to infect birds, both domestic and untamed. As the disease exerts diverse impacts on many body organs, clinical signs are considered to be relatively varied. One typical sign of pathogen-carrying hosts is chronic and continuous wasting, lassitude, and watery diarrhea [42]. Some susceptible birds may present with respiratory signs which sometimes

lead to granulomatous ocular lesions and sudden death. In human, components of *M. avium* are potentially inducing long-term disease, mostly found in immune-deficient patients [43]. Introduction of local injury infections with enlarged lymph nodes is a typical indication of the mycobacteriosis. Nevertheless, the transmissible incidence is extremely diminutive, only occurs in severely debilitated person. Transmission routes comprise ingestion of tainted food or water polluted with feces from shedders [44]. In Vietnam, it was estimated around 145,000 cases of Avian Tuberculosis in the year 1997, which caused dispersed sickness in patients suffering from AIDS [45]. To cope with this problem, close supervision of handling open live animals or other avian-related material must be applied with adequate bio-risk management.

Chlamydiosis (psittacosis or parrot fever)

Chlamydophila psittaci is basically presented by scientists as a bacterial organism that emerges in a widespread manner and has adverse influences in excess of 100 avian species [46]. The malady is also adapted to parrot fever while it causes actual illness in birds belonging to Psittaciformes order or parrot-like birds [47]. Chlamydiosis is highly contagious by human inspiration of pestiferous fecal dust and extensive dispersion by carrier birds which exist as the primary reservoir for the infection. After invading the host's immunity, the infectious microorganism is secreted in both excreta and nasal discharge, which can last for years. Clinical signs vary from moderate respiratory depression to serious pneumonia, accompanied by diarrhea, conjunctivitis, or arthritis. *C. psittaci* is capable of remaining extant during harsh conditions such as drying or frosty weather [48]. Therefore, this ability allows the organism to be spread on bedraggled clothing and equipment. Other routes of disease transmission include bird-to-bird, feces-to-bird, bird-to-human transmission, or even human-to-human infection primarily by exposure to contagious saliva [49]. However, chlamydiosis infection in human beings is exceedingly infrequent and often improperly investigated. A case of chlamydiosis occurred on a 10-year-old boy—who was previously reported with relentless fever, acute abdominal cramping, pneumonia, and neurological disorders [50]. The child's house has disclosed the presence of two parrots; the older brother of this patient was identified with high level of anti-*C. psittaci* IgA, considering a sub-clinical chlamydiosis. Currently, few cases of psittacosis on human were reported in Southeast Asia, whereas this infection has not antecedently been informed in Vietnam [51].

Allergic alveolitis

Despite having been ambiguously identified as a zoonotic disease, *Allergic alveolitis* is remaining its serious threat to global human population [52]. It is also renowned for other denominations such as hypersensitivity pneumonitis, parakeet dander pneumoconiosis, and pigeon lung disease [53]. In human, especially for owners of pet or captive breeding birds, this specific *alveolitis* is resulted by adjacent contact with feather exfoliation, dust, and droppings of birds. One inscrutable factor about the disease is that though infected animals show particular clinical signs amid 2 years, it may take about 10–20 years of progressive exposure. Once the disease happens, it may be acute, sub-acute, or chronic [54]. Hosts with acute infection show signs of coughing, dyspnea, high febrile… within 4–8 h of exposure to discernible level of feather dander and fecal matters. With longer time of exposure to infectious derivation, sub-acute signs express with dry cough, continuous breathing obstacles plus weight loss in case of chronic infection. The symptoms are relatively serious and often be misunderstood for a deliberating cold or influenza virus. Enduring lung complications may extend with chronic alveolitis—comprising of a worsen infection called pulmonary fibrosis, which prevents patients from inhaling properly. For worldwide distribution, a case of a 53-year-old Indian woman showing seriously prolonged breathlessness was confirmed with *Allergic alveolitis* after quotidian exposure to pigeons for nearly 35 years [55]. In the USA, the prevalence stood at 6000–21,000 cases per 100,000 individual annually for pigeon farmer [56], yet the infectious incidence has been little-known in Vietnam.

Giardia

Considering the foremost frequent digestive parasites affecting humans, roughly 200 million residents in Asia, Africa, and also America acquire clinical illnesses derived by *Giardia duodenalis/G. intestinalis/G. lamblia* [57]. As the parasites invaded the host immunity, *Giardia* gives rise to a typically self-restricted clinical infection delineated by watery diarrhea, abdominal spasm, anorexia, bloating, and weight growth retardation [58]. Nevertheless, sub-clinical giardiasis was likewise ubiquitous, mostly found among developing countries. In other animal species, *Giardia duodenalis* commonly results in mild enteric disorders in both human and mammals. This induces Giardiasis as one of the most prevalent zoonotic diseases around the world [59]. For epidemiological aspects, *Giardia* has direct life cycle and is capable of becoming infectious as it is encysted and liberated into the fecal matter. Cysts are considered durable and can cause infectious illnesses up to several months in cool, soaked regions following by quickly spreading to surrounding habitat. After entering the host body, cysts immediately excyst into the duodenum, discharging the trophozoites. In the last stage, cysts are moved along the digestive tract before releasing in feces. This causes potential transmission by tainted water, foodstuff, fomites, or by direct physical interaction. A paper demonstrated that around 2.4% of children less than the age of 3 with intense

diarrhea in Hanoi was determined with *G. lamblia* [60]. Apparently, healthy citizens in North-western Vietnam accounted for an astonishing result of 4.1% [61].

Campylobacter

Thermophilic *Campylobacter* is the most common bacterial cause of gastroenteritis in humans worldwide. Poultry and poultry products are the main sources for human infections. Epidemiological data concerning campylobacteriosis in Asia are limited. This is influenced by the limited number of laboratory facilities and lack of equipment and awareness in physicians and veterinarians resulting in the lack of surveys. Therefore, it is difficult to accurately assess the burden of *Campylobacter* infections.

Campylobacteriosis, usually derived by *Campylobacter jejuni*, is responsible for prime etiology of bacterial diarrhea in human beings, especially for children under 2 years of age in developing countries [62]. It is estimated that yearly cases of diarrhea are approximately between 850,000 and exceeding 2 million [63], more than 70% of global cases are related to utilization of chicken meat [64]. Even though pathogenic agents are destroyed during cooking process, the problem originates from murky food handling practices and the commingling between raw poultry products with other foodstuffs. Infected patients usually suffer from mild, intermittent gastroenteritis, abdominal spasm, benign to bloody diarrhea, or sometimes febrile. In the case of immune-compromised patients, the disease' progression may be complicated with fatality or future sequelae such as muscular pain, nephritis, arthritis, myocarditis [65]… In laying hens, the condition transferred from vibrionic hepatitis in the past to sub-clinical infection in poultry. The organisms are regular dwellers of avian alimentary tract and poultry may harbor voluminous colonization without any detrimental impacts. Once the agent is introduced into the shelter, it spread pervasively and vitiating greater than 90% of birds during 2 weeks [66]. The bacteria are ubiquitous in the surrounding habitat, making it impossible to implement any eradication and surveillance method at the farm level. Amid meat processing, in case there is one tainted carcass, the pathogenic agents can effortlessly defile the gross production chain, thus control method should be imposed on this step of extension. In Vietnam, *C. jejuni* made up nearly 85% of bacteria detected in children clinical cases [67]. Another study in 2005–2006 concluded that Ho Chi Minh City obtained the lowest prevalence of *Campylobacter spp.* with 15.3% among fine cities worldwide [68].

Colibacillosis

E. coli—commonly found in the digestive system and dermal area of animals—is a major etiological agent causing colibacillosis [69]. Considering component of typical bacterial flora, *E. coli* strains are also divergent in their capacity to induce diseases [70]. While numerous strains are not pathogenic, others are likely to cause illnesses in both animals and human. In particular, consuming products which have been tainted with a virulent strain can give rise to drastic infection. For most cases, *E. coli* is presented as an opportunistic pathogen and most *E. coli* diseases are the consequence of complications. In poultry, *E. coli* may lead to septicemia, long-term respirator depression, synovitis, pericarditis, salpingitis, and infectious cellulitis [71]. Typical symptoms in patients infecting with *E. coli* comprise diarrhea and intermittent febrile [72]. Sequelae for scarce genres of *E. coli* infection consist of dysentery, shock, and purple rash. After exposing to the contagious agent, patients are likely to show symptoms between 12 h and 5 days, mostly in 12–72 h period [73]. The treatment application involves managing the severity of diarrhea and dehydration, some detrimental cases may demand the usage of antibiotics or sometimes hospitalization. In Vietnam, research has been conducted on 204 chicken and 510 human fecal samples to evaluate zoonotic transmission of antibiotic resistant *E. coli* among human exposing to pathogenic sources [74]. The outcome was informed with 59.4% positive chicken samples and 20.6% people infected. Given the feasibly stringent consequences of the distribution of *E. coli* from livestock animals to human, enforcement on antibiotic usage should be implemented, both in small scale and backyard farms.

The risk factors which facilitate zoonotic diseases from birds to humans in Vietnam

Eating habit

Considering the transmission method of zoonotic diseases, it is necessary to mention eating custom as a key factor that extends the distribution of these harmful agents. First of all, with the deep-rooted culture of culinary freedom, many Asian people are able to consume almost all species that moves, flies, or swims. This ritual has led to an apparent decline in wildlife animals as well as increased in the potential risks of transmitting zoonotic agents [75]. In Vietnam, thousands of wild birds captured from their natural habitat are being traded without any restrictive policy from the government. In 2016, scientists from TRAFFIC organization inquired bird sellers and mobile vendors in Ho Chi Minh and Ha Noi for their trading status [76]. The outcome was extremely astonishing; more than 8000 birds of 115 different species were sold over a shock period of 3 days. Moreover, it is commonplace to observe numerous flea markets in every corner of Vietnam with such poor hygiene status, sellers displace their products abutting each other, uncovered from any external factors such as dirt, and exhaust fumes. This alarmed situation is ubiquitous

and aware by all people, but this problem is not thoroughly resolved and has been prolonged for years. Poultry products together with pork and beef are in close contact result in cross-contamination of infectious agents, which can further mutate into more virulent form attacking the whole society. In addition, consuming salad-like Vietnamese dish, blood pudding with poor hygiene may elevate the potential for spreading infectious diseases. In some localities, people are acquainted with eating foodstuff with the fingers, this tradition may lead to increase possibilities of zoonotic malady emergence among society.

Scattered, small scale farming

In recent years, the consecutive epidemic surge and transmission of infectious illnesses have caused indispensable consequences on the poultry farming areas, threatened to health care surveillance of human beings and wild birds. Poorly-restricted poultry operations held by local residents—such as backyard farms—are widely expanded and potentially jeopardize to both poultry itself and our human population [77]. In early history, people tend to raise a multitude of animals such as chicken, ducks together with pigs and cattle in relation to their beliefs of providing themselves with stainless, organic meat products. This tendency has been amplified throughout the time, which may bring several downsides compared with the positive impacts. Particularly, damp areas in which backyard poultry has adjoining interaction with feral birds or commercial poultry are at highest risk of obtaining infectious diseases [78]. This worrisome situation can be explained by numerous household farm routines such as poor management practices, insufficient bio-security, vectors, fomites…It is proposed that bulky gatherings of diseases in regions with immense density of poultry flocks are likely to cause epidemic infections [79]. Therefore, infectious agents are capable of proliferating, mutating into more virulent forms in favorable environment. This eventually gives rise to an increasing quantity of zoonotic diseases with periodic occurrence throughout the world in the past decade. Moreover, transportation of poultry together with handling paraphernalia from these locations or live bird markets are routinely defined as major risk factors of zoonotic diseases movement among the society [80]. As the result, backyard farming should undergo scrupulous examination by veterinarians, state agencies more prevalent in order to tackle the problem.

Environment

Contagious diseases are defined to have close relationship with environmental issues in emerging disease hotspots [81]. Relatively, the interaction between nominal span to the most adjacent lake; nearest distance between swampland to national highway and the yearly average rainfall are of pivotal importance in contributing to the extensive expansion of HPAI H5N1 virus in China [82]. The outcomes demonstrate bird populations settled near water sources are more likely to be tainted with illnesses and substantially support the waterfowl's commission in transmitting bird flu. As viruses are shedding through saliva or nasal discharge from infected hosts, people may involuntarily spread out contagious agents to water body by contaminated fomites or infected birds. Other sources of infection are via virus remaining on feathers or fur, which later exposes to water sources after close connection with a diseased individual. The distribution of viruses continues while water body, exemplified as lake, is stationary and bordering with a rearing area or community. Remarkably, the incidence of HPAI H5N1 infections is diminished while the rainfall increases in a particular area. One possible clarification might be that higher precipitation levels might bring about a minor bird population, thus declining opportunities for birds to become infected after exposure to the virus. Another potential factor is considered juxtaposition to national highway in which delivery of poultry and their products across the nation is prioritized. By transporting for long distance, a multitude of birds and animals from distinct backgrounds are captured on acme of each other, providing a perfect environment of cross-contamination of zoonotic diseases. Moreover, as numerous open flea markets are existing along or adjacent to the highways, it may also intensify the opportunities of virus dispersion.

Climate

Climate model has been long-term identified as an underlying risk factor of zoonotic diseases, late in the nineteenth century [83]. For instance, the Roman upper class withdrew to spend their holiday on hill resorts every summer to prevent malaria [84]. Whereas South Asians recognized that steadily curried foodstuffs had lower chances to cause diarrhea in high summer. There are several studies have been published to scientifically strengthen the underlying mechanism of this factor. In case of vector-borne illnesses, ideal climatic situations such as temperature, rainfall, sea level together with airstream, and daytime interval are of pivotal importance in vectors, pathogenic agents, and hosts existence and proliferation [85]. Waterborne infections are closely correlated to human consumption of filthy drinking water, recreational water, or sustenance. This may arise due to unhygienic human activities, such as inopportune discarding of manure wastes, or by weather elements. Precipitation can vastly affect the conveyance and dispersion of pathogen, whereas temperature regulates their development and endurance. In several cases, alterations in infectious disease spreading patterns are a feasibly chief outcome of climate change. As a result, more information should be gathered and analyzed to acquire the

Table 1 Possible carriers, clinical sign, and transmission routes of possible diseases transmitted from birds to human in Vietnam

Diseases	Transmission	Vectors	Clinical signs	Distribution	Prophylactics/Therapeutics	Reference
Avian influenza	Direct contact with affected birds; migratory birds; bird droppings	Mechanical vectors (contaminated equipment, vehicles, feed, cages, clothing, feed, or rodents)	Flu-like illness	Worldwide	M2 inhibitors (amantadine and rimantadine) and the neuraminidase inhibitors (oseltamivir and zanamivir). Vaccination	[88, 89]
Newcastle disease	Direct inoculation	Not reported	Flu-like infection with conjunctivitis and self-limited	Worldwide	Inactivated and attenuated vaccines for poultry use	[90]
Salmonellosis	Direct contact with infected birds Horizontal transmission Vertical transmission by eggs Transovarial route (vertical)	Mechanical vectors (fomites, feed, pests, and vehicles)	Lethargy, anorexia, diarrhea, excessive thirst, arthritis, conjunctivitis, spleen/ kidney/ heart/ liver damage can occur	Worldwide	Antibiotics may be used Adequate cooking kills bacterium Do not eat foods containing raw products Wash hand and work surfaces	[91, 92]
Mycobacteriosis	Ingestion of soil and litter contaminated with fecal material or carcasses of infected birds or by aerosols	Not reported	Cough, weight loss, coughing up blood or mucus, weakness or fatigue, fever and chills, night sweats, lack of appetite, and weight loss	Worldwide	Treatment regime: zithromycin or clarithromycin (with ethambutol as a second drug) Third, or fourth agents can be added: clofazimine, rifabutin, rifampin, ciprofloxacin and amikacin. Taking ART is the best way to prevent MAC for HIV patients.	[93–95]
Chlamydiosis	Direct contact with infected birds, especially parrots, poultry and turkeys. Occupational exposure: handling of infected birds; working in areas where such birds are kept or butchered Dried feces of birds and poultry; dust from feathers and cages	Not reported	Moderate respiratory depression to serious pneumonia, diarrhea, fatigue, conjunctivitis, or arthritis	Worldwide	Antibiotics treatment: tetracycline and doxycycline Wash your hands regularly after handling birds or bird supplies. Avoid touching a bird's beak to your mouth or nose. Take birds that look sick to the veterinarian. Keep birds in a well-ventilated area.	[96, 97]
Allergic Alveolitis	Inhalation of and sensitization to antigens derived from protozoa, molds, animals, insects, bacteria, chemicals, and other organic materials	Not reported	Cough, dyspnoea, chest tightness, chills, shortness of breath, sweating, malaise, fatigue, myalgia, and headache occurring 4 to 6 h after antigen exposure	Unknown	Avoidance of the causative antigen Corticosteroid therapy Oral prednisone therapy (between 40 and 60 mg) Education may prevent respiratory problems in high-risk environments Major preventive measures (mask wearing, increasing barn ventilation, avoiding the barn when the animals are feeding)	[98, 99]
Giardia	Direct contact with infected humans or animals Person to person and animal to person	Not reported	Diarrhea, abdominal cramps, bloating, weight loss, and malabsorption	Worldwide	Medications: metronidazole, tinidazole, nitazoxanide Public health education Protecting	[100, 101]

Table 1 (continued)

Diseases	Transmission	Vectors	Clinical signs	Distribution	Prophylactics/Therapeutics	Reference
	via hand-to-mouth transfer of cysts from infected feces or fecally contaminated surfaces. Waterborne outbreaks via fecal contamination of public water supplies or recreational swimming areas.				public and private water supplies against fecal contamination Educating travelers about the need for safe food and water consumption	
Campylobacter	Foodborne, via undercooked meat and meat products, raw or contaminated milk. Contaminated water or ice	House fly (*M. domestica*) Stable fly, *Stomoxys calcitrans (L.)* Black dump fly, *Hydrotaea aenescens (Wiedemann)*, Root-maggot fly, *Adia cinerella (Fallén)*	Diarrhea (frequently bloody), abdominal pain, fever, headache, nausea, and/or vomiting	Worldwide	Self-limiting Symptomatic treatment by liquid and electrolyte replacement Sufficient cooking of raw meat Good personal and environmental hygiene Avoid contact with sick or dead birds and their discharges Wash hands thoroughly after dealing with birds and its products Do not drink untreated water	[102, 103]
Colibacillosis	Inhalation of the faecally contaminated dust that contains large numbers of pathogenic *E. coli*.	Not reported	Profuse and watery diarrhea, abdominal colic fatigue, weight loss and intermittent febrile	Worldwide	Antibiotics treatment Elimination of predisposing factors (birds vaccination against mycoplasmas, IBV and NDV) Wearing protective clothing when handling birds, eggs or body tissues Wash hands thoroughly after dealing with birds and its products	[104, 105]

fundamental causal relationships, then apply the findings to future forecast of increasingly complex zoonotic diseases.

Public awareness and behaviors

Public awareness of zoonotic diseases has an essential role in disease preventative measures; a shortage of sufficient knowledge of infectious diseases may bring about low detection rates, the disruption of treatment, partiality, and stigma. As the total number of poultry in Vietnam continues to rise, contact with poultry is one component of daily activities and work lives. This creates more opportunities for infectious diseases to spread into the human populations. Especially for residents living in rural and regional areas, it is crucial to provide them with accessible resources of serious consequences caused by emerging zoonotic disease. For the past years, Vietnamese government has conducted several educational programs, together with community-based advertisements, which appeared to have some effective outcomes on rural populations [86]. In 2014, a research was performed to investigate public health knowledge and attitudes in rural regions of Vietnam as well as their alleviation procedure [87]. Farmers showed high level of awareness on the hazardous distribution of avian influenza or parasites from livestock via water. On the contrary, there were fewer farmers who acknowledged that bacteria, such as *E. coli*, could transmit from livestock to humans through water sources. Though more than 70% of commercial farmers purify and/or boil their drinking water, other primary protection measures—such as hand washing, safety protective clothing—were not popular. Concerning this matter, educational intervention should be conducted regularly by propagating information through lectures, appealing performances, educational songs, and interactive games. This may encourage the locals to obtain an early approach to healthcare, and motivate people to follow hygiene standards including the use of gloves, masks, and soap. Changing people behaviors and habits is not a one-time event; it requires close correlation between the government and the society to ensure the efficacy of this action. Eventually, routine assessment of the awareness levels in rural citizens is particularly crucial because it allows for better understanding of the outcome of previous prevention endeavor accomplished by the government and evaluates the demand for interventions.

Conclusions

Zoonotic diseases (Table 1) from poultry have become a topic of concern among society residing in both countryside and metropolitan region. Though the incidence is quite scant, human infected with avian-causing diseases tend to encounter with relatively high mortality rate and various subsequent complications. Therefore, all individuals, especially who live near areas where open live markets are dominated, should be cautious and apply self-defense apparatus such as masks and protective clothes. Indeed, global outbursts of poultry illnesses will probably continue to make front-page headlines every year in Asian countries, especially Southeast Asia. Unless the citizens are willing to change their poor rearing practices of backyard farming, zoonotic illnesses are inclined to grow in popularity and detain human health in the area. For owners of pet birds, the risks of exposing to pathogenic agents maybe lower but still require to have further investigation. In conclusion, as human epidemics associated with avian-originated zoonotic diseases were to erupt in the area, rapid restriction of all possible routes of transmission would be our highest demand. Such an effort would involve the expansive deployment of antiviral medicine, private protection appliances, and other sources. Meanwhile, veterinarians are demanded to be equipped with sufficient knowledge to counsel and instruct the public on the mythologies and realities towards the jeopardize of poultry zoonoses.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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