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REVIEW

The possible zoonotic diseases transferring from pig to human in Vietnam

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Abstract

Southeast Asia is considered one of worldwide hotspots consisting many distinct zoonotic infections. With optimal condition for the development of various pathogens, Vietnam is facing serious risks of zoonotic diseases. Besides, more than 50% Vietnamese people settle in rustic areas and earn their livings through small-scale animal breeding. It is possible that zoonotic diseases can be easily spread to the population by close contact with the infected animals, their infected residues, contaminated water, soil, or other possible means of transmission. In fact, zoonotic infections—transmissible infections between vertebrate animals and humans—cover a wide range of diseases with distinctive clinical and epidemiological highlights. With insufficient understanding and swift alteration in toxicity of the pathogens, these infections have gained more concerns due to sophisticated routes of transmission and harmful threats to humans. Recently emerging viral diseases exerted potential dangers to human beings, which required many countries to impose immediate actions to prevent any complications. Vietnam has recorded several cases of zoonotic diseases, especially pig-related illnesses; however, the studies on these diseases in this country remain limited. This work aims to highlight the zoonotic diseases transferring from pigs to humans and discuss risk factors of these diseases in Vietnam.

Keywords Zoonotic diseases · Zoonotic infections · Emerging diseases · Pig · Vietnam

Introduction

Zoonotic diseases often occur when people are expose to infected animals, which promotes serious concerns from the society as pathogens can transmit from animals to human. As the largest pork-supply chain in Southeast Asia, pigs are of paramount importance in Vietnam due to their benefaction to human sustenance, their commission in agronomic production structures, and their economic engagement [1]. Several swine diseases are reported to have the capacities of transferring to human from vertebrate animals [2]. Potential pathogens causing these diseases are acknowledged to be various and comprise microscopic organisms such as bacteria, viruses, parasites,

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and fungi [3, 4]. However, most diseases are mild and efficiently forestalled with basic methods like wearing defensive equipment and proper hand washing [5]. Nevertheless, more virulent strains of these microbes still existed worldwide, which caused serious illness in pigs and possibly leads to lethal cases in humans [6]. It is estimated that 17 million deaths annually worldwide are induced by infectious diseases [7]. Recently emerging zoonotic diseases are conceivably diffused to human being by multitude routes such as direct transmission between animals and humans, vector-borne infections, or infectious cases in which marine and terrestrial animals play as a reservoir for illness spread, including potential exposure to contaminated human food and water sources [8–10]. Common zoonotic infections acquired from pigs are tuberculosis, *Streptococcus suis*, leptospirosis, influenza, etc. [11, 12]. For two decades, Vietnam has experienced exceptional advancement in economics and thus increases residents' living standard. Meanwhile, quick urbanization and escalated animal production to meet the demand of the increasing population resulted in some negative impacts on human health such as inflated risk of zoonotic disease transmission [13]. In Vietnam, poorly restricted food production schemes with miscellaneous species and deficient biosecurity, slaughterhouses, and damp marketplaces operating with negligible fundamental sanitation, inadequate supply chains for meat conveyance, ingesting of rare/undercooked blood, flesh-originated products, and remote animal trading enhance hazardous probability of zoonotic disease transmission [14]. Vietnam has reported several human cases of zoonotic diseases from pigs such as 48 patients with *Streptococcus suis* (three mortality in Tra Vinh, Lai Chau, and Ba Ria-Vung Tau) and 19 people infected with meningococcal meningitis in 2018, according to the Health Department of Vietnam [15]. In Son La province, 74 people have contracted viral encephalitis in eight districts (37 cases higher compared to last year), including one death in Thuan Chau district. But, only few researches on zoonotic diseases in Vietnam have been published. So, to provide better insight of zoonotic situation in Vietnam, this work is implemented to highlight more plausible information and discuss risk factors and applicable prevention methods to cope with this problem in Vietnam.

Zoonotic diseases caused by virus or bacteria

Swine influenza

Swine flu is categorized as a respirational illness originated by type A influenza viruses that frequently cause epidemics of flu in pigs [16]. Swine influenza infections can result in increased levels of sickness in swine, but usually lead to few casualties due to mild sickness [10]. Common clinical signs detected in pigs include fever, coughing (barking), depression, nasal and ocular discharge, sneezing, breathing troubles, eye redness or irritation, and going off feed [10]. Swine flu infections may happen among swine all through the year, but most cases occur amid the late autumn and winter months which are comparable to flare-ups of seasonal flu in human [8]. Pregnant women, newborns, and children under the age of two are considered groups with expanded hazard for complications emerging from swine flu, stated by the World Health Organization (WHO) [17]. In general, influenza infections can be specifically transmitted from pigs to human and from human to pigs [18]. The swine H1N1 infection was first reported worldwide in 2009 and was causal claim for more than 17,000 deaths [19]. Some substrains of the virus are endemic in people and responsible for limited proportion of all regular flu, whereas others are endemic in pigs and fowls, superiorly known as swine flu and avian flu. Whereas, the initial instance of swine influenza in human in Vietnam was informed on 31 May 2009, which just arrived back from America on 26 May 2009 [20]. Since then, the authority established thorough surveillance to control the spread of disease to protect the population from this emerging disease. Despite the strict regulation, Vietnam has recently recorded more than 11,000 human cases of H1N1 infection over the 9-year period (from 2009 to 2018), including first fatal case reported in April 2013 [21].

Foot and mouth disease

Foot-and-mouth disease (FMD) is widely branded as a profoundly infectious, intense viral diseases pertained to *Aphthovirus* genus of cloven-hoofed animals, major clinical signs detected by febrile, anorexia, depression, lameness, and the presence of copious vesicles on the feet and some scattered around the mouth [22]. In human, the disease is mainly self-limiting and has mild symptoms [23]. It is mostly detected among young children with common clinical signs of febrile, oral sore, and urticaria on the hands, feet, and buttocks. The oral injuries comprise ulcerating follicle on the buccal conjunctiva, tongue, palate, and gums [23]. The rash is presented with papulo-vesicular abrasions on the palms, digits, and soles, which usually endure for 7 to 10 days, and maculopapular scratches on the buttocks [24]. Infection in human has been described primarily in association with utilization of unpasteurized dairy merchandises or untreated meat items from tainted animals or through direct connection with infected hosts (e.g., agronomists and veterinarians) [25]. No mutual transmission between human in the population has been informed. Even though several cases and outbreaks of FMD in animals were reported [26, 27], no cases in humans infected with FMD virus have been detected in Vietnam.

Streptococcus suis

Streptococcus suis (*S. suis*) is defined as a gram-positive strain of pathogenic bacteria that exemplifies rudimentary health detriment in the pig-raising industry around the world [28]. *S. suis* frequently occupies within the upper respiratory tract such as tonsils and nasal cavities; the bacteria can also be found in genital and digestive tracts in piglets in some cases [29]. In addition to the elementary host—swine, this pathogen has previously been detected from a myriad of other species such as equine, canine, and feline [15, 28]. Recently, few varieties of *S. suis* have converted into highly pathogenic zoonotic factor that can cause meningitis, septicemia, joint pain, and indeed streptococcal harmful mental disorders (which subsequently lead to hasty mortality in some cases) in affected human [30]. Shortly after the expansive outbreaks of *Streptococcus* diseases in China, increasing worries towards public health issue and surveillance method have been promoted in 2015 [29]. Infection might be obtained by direct interaction with rare or undercooked flesh-originated items, which is customarily experienced within the Far East of Asia [31]. In Vietnam, microbiological research on cerebrospinal fluid with possible CNS infection from more than 2000 patients was conducted between 1996 and 2010. The outcomes have acknowledged *Streptococcus suis* serotype 2 in 8.9–33.6% among the tested samples [15, 30, 32], authorizing *S. suis* accounted for the greatest feasible source causing bacterial meningitis in adults. Approximately 66% of patients encountered auditory dysfunction as a complication [15]. Several hazardous factors that result in these diseases include consuming undercooked pig blood/intestine, occupational hazards, and close contact with pigs while possessing dermal abrasions [33]. Because of ineffective legislation on supervising pigs' medical conditions, slaughterhouse may harbor sick pigs, thus causing a tremendous hazard to both workers and meat consumers.

Anthrax

Anthrax is a severe contagious infection caused by gram-positive, rod-shaped microscopic organism known as *Bacillus anthracis* [34]. *Bacillus anthracis* mainly exists in nature in the form of spores so that it can durably sustain in rigid environment for decades [35]. These bacteria can grow at 37 °C in typical laboratory culture and cause thrombosis in cattle such as cattle, goats, and sheep [36]. Anthrax is usually found in people who are involved in animal husbandry, veterinary medicine, and contaminated meat eaters. Commonly, these bacteria can be found in soil and influences companion and wild animals around the world [5]. Despite its scarce occurrence, individuals can get infected with *Bacillus anthracis* in case they encounter contaminated animals or animal products. Researchers have identified four types of sickness that a person develops based on how microbes enter the body: cutaneous (skin), inhalation, gastrointestinal, and the recently nominated injection anthrax [37]. Generally, anthrax gets into the human body through dermal surface, lungs, or alimentary tract [38]. These types can be deliberated and cause death if no suitable antibiotics are implemented during the infected period [36]. Based on the disease's severe consequences on human's health, anthrax was wickedly exploited as biological weapon in early 1900s, amid World War II. Currently, nearly 2000 cases infected with anthrax are reported around the world [39, 40]. In 2014, nine people have been announced with symptoms of cutaneous anthrax in a Vietnam's northern province—Ha Giang [41]. Further investigation showed that they have previously been exposed to the handling and contaminated meat consumption. Even though no fatalities were reported, it has exerted perilous alert on the community to carefully quarantine infected animals, especially in high-risk areas.

Tuberculosis

Tuberculosis (TB) is a ubiquitous contagion triggered by airborne bacteria termed *Mycobacterium tuberculosis* [42]. TB invades the human body through inhaling smudged aerosol droplets coughed or sneezed by infected individual [43]. Humans are also capable of being tainted with tuberculosis by consuming unpasteurized dairy commodities contaminated with *Mycobacterium bovis* [44, 45]. The most usual way of disease is pulmonary TB which mainly attacks the lungs [46]. In particular situations, the pathogen can vitiate the lymph, central nervous system or urogenital area, joints, and skeletons [47]. *Mycobacterium tuberculosis* is displayed around the world and regularly spreads in cramped, stuffed conditions [48]. There remains no prove that pulmonary tuberculosis is transmitted with higher efficacy in aircrafts or dissimilar categories of communal carriage. In fact, tuberculosis is likely to infect long-duration voyagers, human being suffered from a debilitated immune system, or sojourning friends and relations in areas [49]. In 2016, 10.4 million individuals got affected with TB illness worldwide, whereas 1.7 million TB-originated deaths were estimated [50]. It is detected that Vietnam has experienced approximately 17,000 death cases from tuberculosis annually, two times as high as the yearly casualty caused by traffic accidents [51]. Each year, this increasing figure can be up to 180,000 people infected with active TB; 5000 of those cases are categorized as multi-drug resistant (MDR) tuberculosis [52]. Nevertheless, merely 52% of patients with TB in Vietnam are supplied with adequate treatment due to economic constraints and remote areas' residents [53].

Campylobacteriosis

Campylobacteriosis is a type of infectious disease resulting by members of the bacterial genus *Campylobacter* [54]. The primary genre of public health significance is considered *Campylobacter enteritis* in terms of *C. jejuni* and *C. coli*, among which *Campylobacter jejuni* is the foremost etiology of bacteria-originated gastroenteritis around the earth land [55]. Within the developed countries, campylobacteriosis is frequently procured by intake of under-prepared poultry, whereas among less developed nations, it is more regularly invaded through contamination with drinking water [4]. Once the bacteria enter the body, it will prevent fluid reabsorption from the digestive system after the attachment to the intestinal epithelium or mucus deposit. This will further induce irritation and diarrhea in infected hosts in several days [56]. Meanwhile, campylobacteriosis is generally moderate, and treatment with anti-microbials merely diminishes the length of gastrointestinal indications by 1.32 days; a few associations have prompted against anti-microbial usage in unproblematic situations [56]. However, the incidence of the infection has been expanding, with the number of infected cases regularly surpassing those of salmonellosis and shigellosis [57]. In 2006, 100 samples of chicken breast were gathered for measuring bacterial presence succeeding the ISO 10272 standards [55]. Thirty-one percent of tested samples were detected with *Campylobacter* spp. with *C. jejuni* accounted for 45.2% and *C. coli* for 25.8%.

Brucellosis

Brucellosis is commonly defined as illnesses originated by gram-negative coccobacilli pertaining to *Brucella* genus [58]. This genus is extensively diverse in terms of distinct nomenclature such as *Brucella abortus*, *Brucella ovis*, *Brucella suis*, *Brucella melitensis*, and *Brucella canis*, which are related to malady in cattle, sheep, swine, goats, and canine [59]. Specifically, brucellosis is illnesses that facultatively live within the host' cells and is confiscated by macrophages and monocytes. These pathogenic agents will further spread through the host's body to the liver, spleen, lymph hubs, and bone marrow. Major clinical expressions associated with an anaphylaxis of disorder in animals accounted for abortion, stillbirth, and the birth delivery of frail descendant [60]. Meanwhile, numerous *Brucella* species are potentially zoonotic and transmissible from animals to human population [61]. Brucellosis-affected residents regularly occur by interacting with tainted animals or through consumption of foodstuffs manufactured from unhygienic sources. In symptomatic situations, illness introduction is exceedingly variable and may emerge quickly or continuously. Basically, diseases of *Brucella* spp. are sub-acute, intermittent febrile presentation with high fever, headache, itchy, malaise, etc. A few people may recuperate rapidly, whereas others progress to relentless, protracted sequela ranging from joint pain, spondylitis, endocarditis, dermatitis, persistent weakness, and neurological complications. The illnesses can be treated utilizing antimicrobials; nonetheless, diseases can be recurred in many cases despite obvious bacteriological treatment [62]. Between June 2016 and January 2017, a research on human *Brucella melitensis* diseases was conducted in The Hospital for Tropical Diseases (HTD) in Ho Chi Minh City [63]. Ten patients with high body temperature were confirmed to have *B. melitensis* which were further classified into 4 subgroups deriving from Southern Europe, Center East, and China.

Zoonotic diseases caused by parasites

Leptospira

Leptospirosis is widely distributed around the world and possibly lethal zoonosis [64]. The disease is enzootic in numerous sultry areas and engenders expansive outbreaks subsequent to overwhelming rainstorm and deluge. Contagion originates from straightforward or indirect exposure with tainted factors that transmit the infectious agents in the tubules of their kidneys to the surrounding areas via their urine [65]. The bacteria can invade inside the body through incisions and scratches on mucous membrane such as oral, conjunctival, or genital exteriors [66]. The brown rat—scientific term as *Rattus norvegicus*—is served as the most significant derivation of human infections; thus, slum dwellers residing in such insufficient sanitation and destitute lodging are at urgent liability of rodent exposure and leptospirosis [67]. In fact, people with professions at highest jeopardy for direct engagement with possibly ill animals include slaughter men, veterinarians, farm employers, hunters, and scientists [68]. An introductory endeavor to assemble worldwide information on the frequency of leptospirosis was distributed over 15-year period [69]. According to worldwide statistics composed by International Leptospirosis Society researches, the prevalence was evaluated to stand at 350,000–500,000 serious cases yearly [70]. Hazardous populations include citizens of residential areas, bus station, docks, cramped motels, and slums located adjacent to contaminated water canals [68]. These areas contribute with high prevalence of mice, which are primary vectors of leptospirosis in human [71] and considered the most frequent source of intense fever of obscure [72]. Vietnam has recorded many cases of *Leptospira* in human such as 369 *Leptospira* cases detected in this country during a period of 2002–2011 [73].

Trichinella

Trichinellosis is recognized as one of the foremost extensively disseminated zoonoses and instigated by contagion with round worms of the genus *Trichinella* [74]. Disease often arises after ingesting larvae within the muscle of infested hosts [75]. The seriousness of human infection depends on numerous components comprising the quantity of viable larvae obtained, the prevalence of ingesting contaminated meat, cooking status, *Trichinella* species, and the person susceptibility [76]. In terms of local distribution, *Trichinella* spp. can be noticed all through Southeast Asia, from austral region of China to the Indonesian islands in inland pigs and wildlife, initiating persistent outbursts of infection among human being [74, 77]. Three omnipresent species of *Trichinella* have been documented within the Asian locale: the typified *T. spiralis*, non-encapsulated *T. pseudospiralis*, and *T. papuae* [78]. In brutal incidence, patients ingested high number of larvae generally showed up with reduced weight, diarrhea, abdominal discomfort, febrile, myalgia, edema, itch, and maybe death. This disease was reported in 55 nations globally [74]. Between 1986 and 2009, studies announced 65,818 cases and 42 losses spotted from 41 countries; 87% in total were archived within the European World Wellbeing Organization (WHO) area [75]. In Asian countries, *Trichinella* spp. contaminations were reported among people in 18 nations [74]. These zoonotic parasites were mostly found in Southeast Asian nations, but statistical information is not meticulously conducted [74, 79]. *Trichinella* sp. was first recognized in 1923 in two (0.04%) of 4952 pigs examined in Hanoi, Vietnam [80]. Also, in 1953, *Trichinella* infection was identified amid six militias in Saigon with 2 casualties; the source of disease was a fetal pig [81].

Taenia solium

Taenia solium is considered as a recently emerging human plague, infecting thousands of people worldwide [82]. Clinical signs of cysticercosis in public involved hypodermal knobs, epileptic convulsions, serious headache, disabled eyesight, and reminiscence misfortune. There are three separate species of *Taenia* that have been recognized in Vietnam, which are *Taenia solium*, *Taenia saginata*, and *Taenia asiatica* founded on integrated morphology and molecular strategies. Within the typical cycle of transmission of this tapeworm, the adult parasites are found inside the small intestine of patients who appear as definitive hosts [83]. Every day, thousands of infective eggs are segregated from the distal end of the adult tapeworm into feces before spreading to the surrounding environment [84]. The feces with *T. solium* eggs are then ingested by pigs in farms where inappropriate disposal of human feces and poor biosecurity are ubiquitous [85]. This parasite-infected pork, not properly cooked, is likely to cause widespread cysticercosis in the population [85]. *T. solium* is widely found around the world, but it is more commonly seen in cosmopolitan ranges where individuals reside in close connection with hogs and consume undercooked pork such as pork sausages and fermented pork roll. In Vietnam, documents on taeniasis and cysticercosis cited that these parasites dispersed in more than 50 of 63 areas [86]. In several endemic regions, the incidence of taeniasis accounted for 0.2–12.0%, whereas cysticercosis registers 1.0–7.2% of the population.

Ascariasis

Ascariasis is defined as an illness caused by a parasite known as *Ascaris lumbricoides* [87]. It can be classified as nematode or roundworm [87]. However, the swine ascarid, *Ascaris suum*, sometimes infect humans which raises debate if *A. lumbricoides* and *A. suum* are dissimilar species [88]. *Ascaris lumbricoides*, generally linked with pneumonia-like syndrome, is denoted as the largest intestinal roundworm detected in humans [89]. Because of the high density, it currently infects 807 million−1.2 billion humans around the world [90]. Most cases incubating *A. lumbricoides* appear no signs of disease with the roundworm [91]. Some people may be found with early pulmonary indications and eosinophilia during the larval migration of the parasite. In some cases, *A. lumbricoides* can cause lethal contagion from the worm bolus or ectopic movement of the worms. Practically, children are infested with *Ascaris* at an early age, with high occurrence already among preschool children [92]. Between 1990 and 2001, a research was conducted on 29 of the 61 provinces on the current situation of soil-transmitted parasites in Vietnam [93]. The result presented that 33.9 million people were infected with *Ascaris*, accounting 44.4% of the population.

The risk factors which facilitate zoonotic diseases from pig to human in Vietnam

Eating habit

Human utilization of rare/under-prepared meat and animal products is significant source of hazardous element for acquiring various infectious diseases [94]. Throughout the final decades, it continued with alterations in diet predilection and eating customs; ready-to-eat sustenance, in addition to unconventional consuming products, has initiated novel conditions where causative agents might be presented and transmit diseases to the society [95]. Alterations in alimentary preferences were considered as major acumen for mutation of helminth zoonoses comprising capillariasis, anisakiasis, and gnathostomiasis [96]. Many years ago, humans' utilization of unprocessed meat and fishes was related with explicit beliefs and citizen practices. Nevertheless, together with changing purchaser behaviors, expanded universal peregrination, globalization of nutritional merchandise, and intercontinental eating propensities, diseases once categorized as uncommon infections of separate topographical dispersal are presently transforming to be progressively more ubiquitous [97]. In Vietnam, pig blood together with other animals' blood is used in an acclaimed dish called "tiet canh"—raw blood pudding [98]. The major ingredients of pig blood pudding compose of coagulated, raw blood blended with chopped cooked pork tissues. Common bacteria related with the utilization of "tiet canh" is *Streptococcus suis*, in which zoonotic disease is often known as foodborne zoonosis (FBZ) [99]. In 2015, 5 cases of swine streptococcus infections were reported from Tropical Disease Hospital in Hanoi, including three people who ate pudding and two cases died [100]. Another fatal case of swine bacterial infection after eating raw blood pudding was a man from Thai Binh Province [101]. Despite drastic campaigns to control this practice, number of people acquired foodborne diseases has the tendency to grow every year.

Environment

For many years, mutual relationship between environmental changes and zoonotic disease hazards has become the subject of concern among scientists [2]. Most disease agents are transmitted to people either specifically from infected animals or indirectly by means of vectors containing causative pathogens [102]. In few cases, pathogens can endure within the external environment; for example, zoonotic parasites, protozoans, bacteria, mold, and viruses can persevere in soil and marine sources, which can afterward be diffused to people [103]. Impacts of natural changes on zoonotic pathogens can present in numerous patterns [2]. To begin with, changing atmosphere can directly influence pathogen loads in infected hosts, for example, by deliberating the host's immunity to specific infectious factors. In addition, species structure or densities of host or vector networks can be influenced by alternatives in surrounding environment. Moreover, prevalence of close contact between zoonotic carriers, people, and vector plays an important role in manipulating disease incidence. Vietnam—high-risk cohort for the mutation of distinct zoonotic pathogens—encounters with rocket emerge in virulent forms of zoonotic agents such as H5N1, *Streptococcus suis*, and A/H1N1 [14]. However, environmental driver's comprehension of infectious agents transmission from animal hosts to individuals is lack of informative support and relatively ambiguous in some extent. Therefore, more studies should be conducted to disclose the underlying association between environment and the spread of zoonotic diseases.

Climate

Climate change and globalization have raised a pressing issue on emerging and re-emerging animal maladies and zoonoses [104]. Natural environments are contingent on climate change, providing infectious agents with more appropriate climate status. This allows disease-causing microbes such as bacteria, viruses, and parasites to migrate into different locations where they may harm wildlife and

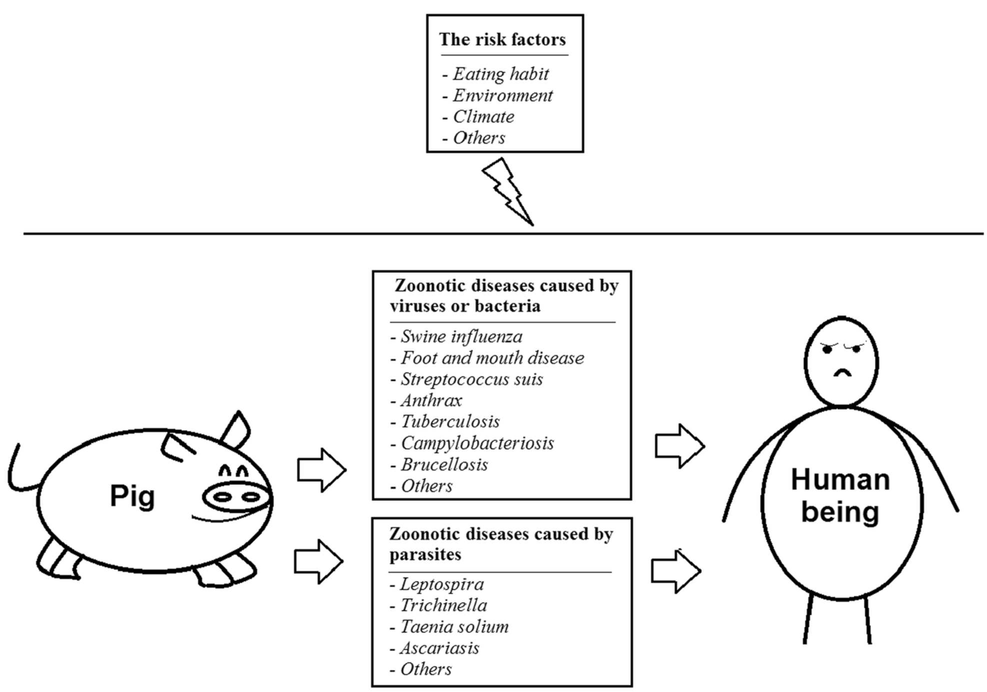

Fig. 1 Schematic illustration of possible zoonotic diseases from pig to human and the associated risk factors in Vietnam

companion species, as well as human beings [105]. Besides, infections that were already restricted only to tropical regions are presently spreading to other previously cooler locations, e.g., malaria [106]. Pathogens that were confined by specific climate cascades can attack new living zones and discover vulnerable species as the climate warms and/or the winters get more benign. Moreover, evidence has proved that global warming is directly linked to the expanding occurrence of tropical infectious diseases in the mid latitudes [107]. Insect-borne illnesses such as trypanosomiasis and anaplasmosis are presently identified in tropical regions where the insect vectors were non-extant within the antecedent. In fact, vector-borne infections especially influenced by climate designs and long-term climatic elements emphatically affect the prevalence of outbreaks. Many sources of these diseases are from insects and the population

Table 1 Possible carriers and preventive methods of infectious diseases transmitted from pig to human

Diseases	Possible carriers	Geographical distribution	Prevention
Swine influenza	Pig, human, turkey, duck, bird, horse	North and South America, Europe, Africa, and parts of Asia	Biosecurity, vaccination, other medical prophylaxis
Foot and mouth disease	Cattle, water buffalo, sheep, goats, pigs, antelope, deer, and bison. Hedgehogs, elephants, llamas, and alpacas may develop mild symptoms	Widespread—particularly in Asia, Africa, and the Middle East	Eradication, biosecurity, quarantine, vaccination program, restriction of animal movement, isolation of infected animals, proper disposal of infected carcass
Streptococcus suis	Pigs, ruminants, cats, dogs, deer, and horses	Worldwide—North to South America, Europe, Asia, Australia, and New Zealand	Sufficient cooking of raw meat, observe good personal and environmental hygiene, avoid contact with sick or dead pigs and their discharges, wash hands thoroughly after dealing with pigs, pork, and its products
Anthrax	Cattle, sheep, goats, antelope, and deer	Central and South America, sub-Saharan Africa, central and southwestern Asia, southern and eastern Europe, the Caribbean	Antibiotics (ciprofloxacin and doxycycline), vaccination program, quarantine, animal dying from anthrax should be urgently reported to public health authorities, safety regulations
Tuberculosis	Humans, cattle, deer, llamas, pigs, domestic cats, wild carnivores (foxes, coyotes), and omnivores (common brushtail possum, mustelids, and rodents)	Africa, Eastern Europe, Asia, Russia, Latin America, Caribbean Islands, Western Pacific region	Improve the scientific evidence base, reduce transmission at the animal-human interface, strengthen intersectoral and collaborative approaches
Campylobacteriosis	Cattle, sheep, chickens, turkeys, dogs, cats, mink, ferrets, pigs, non-human primates, and other species	Worldwide	Implementation of strict biosecurity, insect control, changes in broiler production practices, cleaning and decontamination of transport crates and other equipment
Brucellosis	Cattle, swine, goats, sheep, camels, and dogs	Worldwide—mainly in the Mediterranean region, western Asia, parts of Africa, and Latin America	Control and elimination of the infection in animals, pasteurization of milk, vaccination program, eradication by testing and culling
Leptospira	Cattle, pigs, horses, dogs, rodents, wild animals	Worldwide	Wearing protective clothing for people at occupational risk, avoidance of swimming in contaminated water, vaccination program, eradication, rodent control
Trichinella	Humans, pigs, cats, dogs, horses, pigs, seals, and rodents	Worldwide—mainly in rural areas of South America and Asia	Banning the feeding of raw swill to pigs, application of meat inspection methods for detecting Trichinella, rodent control, eradication, public education, consuming of properly cooked food
Taenia solium	Humans, cattle, pigs, dogs	Worldwide—most common in Latin America, Southeast Asia, and Africa	Strict meat inspection, health education, properly cooking pork and beef well, widespread sanitary installations
Ascariasis	Humans, pigs	Worldwide	Effective sewage disposal systems, adequate cleaning of food to avoid ingesting soil that may be contaminated with human or pig manures, better hygiene, public health education

distribution which is subordinate on changing climate conditions and thus enforce a substantial impact on the occurrence of insects and their topographical dissemination. Milder temperatures also allow insects and microorganism to strongly proliferate and invade in regions where these vectors once could not. In Vietnam, hot weather can be possible explanation of the surge in numbers of cases infected with zoonotic diseases every year [13]. In terms of eating undercooked food, raw blood pudding remaining in intense heat is an idyllic milieu for bacteria to multiply. Especially during Vietnamese Lunar New Year festival, tons of pigs are slaughtered and served with various types of dishes, sometimes raw, which exponentially increases the incidence of patients suffered from zoonotic infections [108].

Implications of the study and directions of future research

As inevitable trend of increasing human population, immense amplification of virulent pathogen means that all scientists are demanded to prepare for possible situations of where and when the subsequent epidemic arises. Though considering an alarming area of public-health problem, there is a shortage of update studies with practical information and data analysis of infectious diseases in Vietnam. In face of this issue, the purpose of this paper is to elucidate specific resources about tremendous progression of some significant zoonotic diseases found in the region. By providing specific data about Vietnam situation, the study emphasizes the widespread and deepening impacts on human race at large. The battle against virulent microorganism needs to be involved by all stakeholders—scientists, politicians, medical practitioners, the financial precinct, and all the community. Researchers may shadow and compare these data into their future assessment of infectious diseases distribution. In considering applicable measures for disease control, this study was composed in the hope that it would act as a useful platform for both scientists and activists who have a strong desire in this field. For those in drug discovery fields, it could provide relevant information about the specific types of pathogens in Vietnam and other Asian countries and human demand on drugs against each type of diseases. However, unless urgent action is implemented by the governments to attract public attention to zoonotic diseases, the problem of epidemic expansion and lethal cases will not be entirely solved. Therefore, as we already perceive potential risks around us, we just need to find a way to cope with it. The upcoming millennium of the human race relies on our actions today.

Conclusions

The negative impact of recently evolving or re-emerging widespread infections of zoonotic derivation in the population might arise possibly disastrous, and thorough examinations of such illnesses are exceedingly disputing. In recent years, Vietnam has encountered several cases of newly emerging zoonotic diseases, which raised concerns not only for the government but other neighboring countries. The supervising of possible outbreaks within the country may confront numerous ambivalence opinions, whether at the standard of species identification, emergent disease cases, or infection epidemics in universal populations. With the vast dissemination of zoonotic diseases transmitted by pigs and the associated risk factors (Fig. 1 and Table 1), it is crucial to impose prophylactic prevention strategies to cope with numerous virulent strains of viruses, bacteria, and parasites in Vietnam. Several researches have proposed probable methods to conquer zoonotic expansion in both developing and developed countries [109]. The recommended outcomes were zoonotic infections training/scholastic modules, zoonotic diseases raising awareness, knowledge and demeanor of individuals about zoonosis, preference of zoonotic illnesses, the function of veterinary public health, and post-exposure prophylaxis. The aggregation of awareness campaign together with instructive programs would be a valuable element and could bring about huge divergence in the prevention and control of zoonotic diseases not only in Vietnam but also for other developed countries.

Compliance with ethical standards

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

Ethical approval Ethical approval is not necessary; this is a review.

Informed consent Informed consent is not necessary; this is a review.

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References

1. Lemke U, Kaufmann B, Thuy LT, Emrich K, Zarate AV (2007) Evaluation of biological and economic efficiency of smallholder pig production systems in North Vietnam. Trop Anim Health Prod 39(4):237–254
2. Estrada-Pena A, Ostfeld RS, Peterson AT, Poulin R, de la Fuente J (2014) Effects of environmental change on zoonotic disease risk: an ecological primer. Trends Parasitol 30(4):205–214. https://doi.org/10.1016/j.pt.2014.02.003
3. Christou L (2011) The global burden of bacterial and viral zoonotic infections. Clin Microbiol Infect 17(3):326–330. https://doi.org/10.1111/j.1469-0691.2010.03441.x

4. Weis AM, Storey DB, Taff CC, Townsend AK, Huang BC, Kong NT, Clothier KA, Spinner A, Byrne BA, Weimer BC (2016) Genomic comparison of *Campylobacter* spp. and their potential for zoonotic transmission between birds, primates, and livestock. Appl Environ Microbiol 82(24):7165–7175. https://doi.org/10.1128/aem.01746-16
5. Chomel BB, Jovme J (2003) Control and prevention of emerging zoonoses. J Vet Med Educ 30(2):145–147
6. Myers KP, Olsen CW, Gray GCJCID (2007) Cases of swine influenza in humans: a review of the literature. Clin Infect Dis 44(8):1084–1088
7. Sarma N (2017) Emerging and re-emerging infectious diseases in South East Asia. Indian J Dermatol 62(5):451–455. https://doi.org/10.4103/ijd.IJD_389_17
8. Lim BH, Mahmood TA (2011) Influenza A H1N1 2009 (swine flu) and pregnancy. J Obstet Gynaecol India 61(4):386–393. https://doi.org/10.1007/s13224-011-0055-2
9. Mishra N (2011) Emerging influenza A/H1N1: challenges and development, vol 2
10. Vincent A, Awada L, Brown I, Chen H, Claes F, Dauphin G, Donis R, Culhane M, Hamilton K, Lewis N, Mumford E, Nguyen T, Parchariyanon S, Pasick J, Pavade G, Pereda A, Peiris M, Saito T, Swenson S, Van Reeth K, Webby R, Wong F, Ciacci-Zanella J (2014) Review of influenza a virus in swine worldwide: a call for increased surveillance and research. Zoonoses Public Health 61(1): 4–17. https://doi.org/10.1111/zph.12049
11. Coulibaly ND, Yameogo KR (2000) Prevalence and control of zoonotic diseases: collaboration between public health workers and veterinarians in Burkina Faso. Acta Trop 76(1):53–57
12. Holt HR, Inthavong P, Khamlome B, Blaszak K, Keokamphe C, Somoulay V, Phongmany A, Durr PA, Graham K, Allen J, Donnelly B, Blacksell SD, Unger F, Grace D, Alonso S, Gilbert J (2016) Endemicity of zoonotic diseases in pigs and humans in lowland and upland Lao PDR: identification of socio-cultural risk factors. PLoS Negl Trop Dis 10(4):e0003913. https://doi.org/10.1371/journal.pntd.0003913
13. Rabaa MA, Tue NT, Phuc TM, Carrique-Mas J, Saylors K, Cotten M, Bryant JE, Nghia HD, Cuong NV, Pham HA, Berto A, Phat VV, Dung TT, Bao LH, Hoa NT, Wertheim H, Nadjm B, Monagin C, van Doorn HR, Rahman M, Tra MP, Campbell JI, Boni MF, Tam PT, van der Hoek L, Simmonds P, Rambaut A, Toan TK, Van Vinh CN, Hien TT, Wolfe N, Farrar JJ, Thwaites G, Kellam P, Woolhouse ME, Baker S (2015) The Vietnam initiative on zoonotic infections (VIZIONS): a strategic approach to studying emerging zoonotic infectious diseases. EcoHealth 12(4):726–735. https://doi.org/10.1007/s10393-015-1061-0
14. Trang do T, Siembieda J, Huong NT, Hung P, Ky VD, Bandyopahyay S, Olowokure B (2015) Prioritization of zoonotic diseases of public health significance in Vietnam. J Infect Dev Ctries 9(12):1315–1322. https://doi.org/10.3855/jidc.6582
15. Mai NT, Hoa NT, Nga TV, Linh le D, Chau TT, Sinh DX, Phu NH, Chuong LV, Diep TS, Campbell J, Nghia HD, Minh TN, Chau NV, de Jong MD, Chinh NT, Hien TT, Farrar J, Schultsz C (2008) *Streptococcus suis* meningitis in adults in Vietnam. Clin Infect Dis 46(5):659–667. https://doi.org/10.1086/527385
16. Galwankar S, Clem A (2009) Swine influenza A (H1N1) strikes a potential for global disaster. J Emerg Trauma Shock 2(2):99–105. https://doi.org/10.4103/0974-2700.50744
17. Silasi M, Cardenas I, Kwon JY, Racicot K, Aldo P, Mor G (2015) Viral infections during pregnancy. Am J Reprod Immunol 73(3): 199–213. https://doi.org/10.1111/aji.12355
18. Ma W, Kahn RE, Richt JA (2008) The pig as a mixing vessel for influenza viruses: human and veterinary implications. J Mol Genet Med 3(1):158–166
19. Skowronski DM, Hottes TS, Janjua NZ, Purych D, Sabaiduc S, Chan T, De Serres G, Gardy J, McElhaney JE, Patrick DM, Petric M (2010) Prevalence of seroprotection against the pandemic (H1N1) virus after the 2009 pandemic. CMAJ 182(17):1851–1856. https://doi.org/10.1503/cmaj.100910
20. Hien TT, Boni MF, Bryant JE, Ngan TT, Wolbers M, Nguyen TD, Truong NT, Dung NT, Ha do Q, Hien VM, Thanh TT, Nhu le NT, Uyen le TT, Nhien PT, Chinh NT, Chau NV, Farrar J, van Doorn HR (2010) Early pandemic influenza (2009 H1N1) in Ho Chi Minh City, Vietnam: a clinical virological and epidemiological analysis. PLoS Med 7(5): e1000277. https://doi.org/10.1371/journal.pmed.1000277
21. VnExpress (2018) Swine flu detected in HCMC's largest hospital. https://e.vnexpress.net/news/news/swine-flu-detected-in-hcmc-s-largest-hospital-3767822.html
22. Grubman MJ, Baxt B (2004) Foot-and-mouth disease. Clin Microbiol Rev 17(2):465–493
23. Prempeh H, Smith R, Muller B (2001) Foot and mouth disease: the human consequences. The health consequences are slight, the economic ones huge. Bmj 322(7286):565–566
24. Mason PW, Grubman MJ (2009) Chapter 22 - foot-and-mouth disease. In: Barrett ADT, Stanberry LR (eds) Vaccines for biodefense and emerging and neglected diseases. Academic Press, London, pp 361–377. https://doi.org/10.1016/B978-0-12-369408-9.00022-6
25. Hyslop NS (1973) Transmission of the virus of foot and mouth disease between animals and man. Bull World Health Organ 49(6):577–585
26. Bertram MR, Vu LT, Pauszek SJ, Brito BP, Hartwig EJ, Smoliga GR, Hoang BH, Phuong NT, Stenfeldt C, Fish IH, Hung VV, Delgado A, VanderWaal K, Rodriguez LL, Long NT, Dung DH, Arzt J (2018) Lack of transmission of foot-and-mouth disease virus from persistently infected cattle to naïve cattle under field conditions in Vietnam. Front Vet Sci 5:174. https://doi.org/10.3389/fvets.2018.00174
27. Vu LT, Long NT, Brito B, Stenfeldt C, Phuong NT, Hoang BH, Pauszek SJ, Hartwig EJ, Smoliga GR, Vu PP, Quang LTV, Hung VV, Tho ND, Dong PV, Minh PQ, Bertram M, Fish IH, Rodriguez LL, Dung DH, Arzt J (2017) First detection of foot-and-mouth disease virus O/Ind-2001d in Vietnam. PLoS One 12(6): e0177361. https://doi.org/10.1371/journal.pone.0177361
28. Feng Y, Zhang H, Wu Z, Wang S, Cao M, Hu D, Wang C (2014) *Streptococcus suis* infection: an emerging/reemerging challenge of bacterial infectious diseases? Virulence 5(4):477–497. https://doi.org/10.4161/viru.28595
29. Yu H, Jing H, Chen Z, Zheng H, Zhu X, Wang H, Wang S, Liu L, Zu R, Luo L, Xiang N, Liu H, Liu X, Shu Y, Lee SS, Chuang SK, Wang Y, Xu J, Yang W (2006) Human *Streptococcus suis* outbreak, Sichuan, China. Emerg Infect Dis 12(6):914–920
30. Wertheim HF, Nghia HD, Taylor W, Schultsz C (2009) *Streptococcus suis*: an emerging human pathogen. Clin Infect Dis 48(5):617–625. https://doi.org/10.1086/596763
31. Goyette-Desjardins G, Auger JP, Xu J, Segura M, Gottschalk M (2014) *Streptococcus suis*, an important pig pathogen and emerging zoonotic agent-an update on the worldwide distribution based on serotyping and sequence typing. Emerg Microbes Infect 3(6): e45. https://doi.org/10.1038/emi.2014.45
32. Ho Dang Trung N, Le Thi PT, Wolbers M, Nguyen Van Minh H, Nguyen Thanh V, Van MP, Thieu NT, Van TL, Song DT, Thi PL, Thi Phuong TN, Van CB, Tang V, Ngoc Anh TH, Nguyen D, Trung TP, Thi Nam LN, Kiem HT, Thi Thanh TN, Campbell J, Caws M, Day J, de Jong MD, Van Vinh CN, Van Doorn HR, Tinh HT, Farrar J, Schultsz C (2012) Aetiologies of central nervous system infection in Viet Nam: a prospective provincial hospital-based descriptive surveillance study. PLoS One 7(5):e37825. https://doi.org/10.1371/journal.pone.0037825
33. Nghia HD, Tule TP, Wolbers M, Thai CQ, Hoang NV, Nga TV, le TP T, Phu NH, Chau TT, Sinh DX, Diep TS, Hang HT, Truong H, Campbell J, Chau NV, Chinh NT, Dung NV, Hoa NT, Spratt BG,

Hien TT, Farrar J, Schultsz C (2011) Risk factors of *Streptococcus suis* infection in Vietnam. A case-control study. PLoS One 6(3): e17604. https://doi.org/10.1371/journal.pone.0017604
34. Berger SA (2013) Anthrax: Global Status. Gideon Informatics, 299 pages
35. Doganay M, Demiraslan H (2015) Human anthrax as a re-emerging disease. Recent Pat Antiinfect Drug Discov 10(1):10–29
36. Li Y, Yin W, Hugh-Jones M, Wang L, Mu D, Ren X, Zeng L, Chen Q, Li W, Wei J, Lai S, Zhou H, Yu H (2017) Epidemiology of human anthrax in China, 1955-2014. Emerg Infect Dis 23(1): 14–21. https://doi.org/10.3201/eid2301.150947
37. World Health Organization (2008) Tuberculosis (TB). http://www.who.int/tb/en/. Accessed 8 June 2018
38. Braun P, Grass G, Aceti A, Serrecchia L, Affuso A, Marino L, Grimaldi S, Pagano S, Hanczaruk M, Georgi E, Northoff B, Scholer A, Schloter M, Antwerpen M, Fasanella A (2015) Microevolution of anthrax from a young ancestor (M.A.Y.A.) suggests a soil-borne life cycle of bacillus anthracis. PLoS One 10(8): e0135346. https://doi.org/10.1371/journal.pone.0135346
39. del Rio-Chiriboga C, Franco-Paredes C (2001) Bioterrorism: a new problem of public health. Salud Publica Mex 43(6):585–588
40. Wallin A, Luksiene Z, Zagminas K, Surkiene G (2007) Public health and bioterrorism: renewed threat of anthrax and smallpox. Medicina (Kaunas) 43(4):278–284
41. Herriman (2017) Vietnam issues hand, foot and mouth disease warning - outbreak news today. http://outbreaknewstoday.com/vietnam-issues-hand-foot-mouth-disease-warning-76944/
42. Borgdorff MW, van Soolingen D (2013) The re-emergence of tuberculosis: what have we learnt from molecular epidemiology? Clin Microbiol Infect 19(10):889–901. https://doi.org/10.1111/1469-0691.12253
43. Thị N, Nguyen VA, Đức Đ (2017) Phân bố dòng vi khuẩn mycobacterium Tuberculosis theo mức độ kháng thuốc ở Việt Nam. Tạp chí Y họ c dự phòng 27:138–145
44. Buddle BM, Wilson T, Luo D, Voges H, Linscott R, Martel E, Lawrence JC, Neill MA (2013) Evaluation of a commercial enzyme-linked immunosorbent assay for the diagnosis of bovine tuberculosis from milk samples from dairy cows. Clin Vaccine Immunol 20(12):1812–1816. https://doi.org/10.1128/cvi.00538-13
45. van Zyl L, du Plessis J, Viljoen J (2015) Cutaneous tuberculosis overview and current treatment regimens. Tuberculosis (Edinb) 95(6):629–638. https://doi.org/10.1016/j.tube.2014.12.006
46. Jia Z, Cheng S, Ma Y, Zhang T, Bai L, Xu W, He X, Zhang P, Zhao J, Christiani DC (2014) Tuberculosis burden in China: a high prevalence of pulmonary tuberculosis in household contacts with and without symptoms. BMC Infect Dis 14:64. https://doi.org/10.1186/1471-2334-14-64
47. Tatar D, Senol G, Alptekin S, Gunes E, Aydin M, Gunes O (2016) Assessment of extrapulmonary tuberculosis in two provinces of Turkey. Iran J Public Health 45(3):305
48. Colbert G, Richey D, Schwartz JC (2012) Widespread tuberculosis including renal involvement. Proc (Baylor Univ Med Cent) 25(3):236–239
49. Daniel TM (2006) The history of tuberculosis. Respir Med 100(11):1862–1870. https://doi.org/10.1016/j.rmed.2006.08.006
50. World Health Organization (2018). Tuberculosis (TB). https://www.who.int/tb/en/. Accessed 06/08/2018
51. Xinhua (2017) Vietnam detects over 100,000 tuberculosis patients annually - Xinhua | English.news.cn. http://www.xinhuanet.com/english/2017-12/13/c_136822637.htm
52. Moitra S, Sen S, Mukherjee S, Das P, Sinha S, Bose M (2015) Study of prevalence and outcome of standardized treatment on category I pulmonary tuberculosis cases in North India: a single center experience. 2(3):83–92. doi:https://doi.org/10.4103/2225-6482.166073
53. Hoang TTT, Nguyen NV, Dinh SN, Nguyen HB, Cobelens F, Thwaites G, Nguyen HT, Nguyen AT, Wright P, Wertheim HFL (2015) Challenges in detection and treatment of multidrug resistant tuberculosis patients in Vietnam. BMC Public Health 15(1): 980. https://doi.org/10.1186/s12889-015-2338-5
54. Kaakoush NO, Castano-Rodriguez N, Mitchell HM, Man SM (2015) Global epidemiology of campylobacter infection. Clin Microbiol Rev 28(3):687–720. https://doi.org/10.1128/cmr.00006-15
55. Luu QH, Tran TH, Phung DC, Nguyen TB (2006) Study on the prevalence of campylobacter spp. from chicken meat in Hanoi, Vietnam. Ann N Y Acad Sci 1081:273–275. https://doi.org/10.1196/annals.1373.036
56. Ternhag A, Asikainen T, Giesecke J, Ekdahl KJCID (2007) A meta-analysis on the effects of antibiotic treatment on duration of symptoms caused by infection with Campylobacter species. Clin Infect Dis 44(5):696–700
57. Altekruse SF, Stern NJ, Fields PI, Swerdlow DL (1999) *Campylobacter jejuni*—an emerging foodborne pathogen. Emerg Infect Dis 5(1):28
58. Zhen Q, Lu Y, Yuan X, Qiu Y, Xu J, Li W, Ke Y, Yu Y, Huang L, Wang Y, Chen Z (2013) Asymptomatic brucellosis infection in humans: implications for diagnosis and prevention. Clin Microbiol Infect 19(9):E395–E397. https://doi.org/10.1111/1469-0691.12250
59. Ficht T (2010) Brucella taxonomy and evolution. Future Microbiol 5(6):859–866. https://doi.org/10.2217/fmb.10.52
60. Department for Environment, Food and Rural Affairs (2014) Brucellosis: how to spot and report the disease. Animal and Plant Health Agency
61. Doganay M (2013) Human Brucellosis: Importance of Brucellosis. Recent patents on anti-infective drug discovery. 8(1):2–3
62. Al-Tawfiq JA, Memish ZA (2013) Antibiotic susceptibility and treatment of brucellosis. Recent patents on anti-infective drug discovery 8(1):51–54
63. Campbell JI, Lan NPH, Phuong PM, Chau LB, Trung Pham D, Guzman-Verri C, Ruiz-Villalobos N, Minh TPT, Munoz Alvaro PM, Moreno E, Thwaites GE, Rabaa MA, Chau NVV, Baker S (2017) Human *Brucella melitensis* infections in southern Vietnam. Clin Microbiol Infect 23(11):788–790. https://doi.org/10.1016/j.cmi.2017.06.028
64. Haake DA, Levett PN (2015) Leptospirosis in humans. Curr Top Microbiol Immunol 387:65–97. https://doi.org/10.1007/978-3-662-45059-8_5
65. Ullmann L, Langoni H (2011) Interactions between environment, wild animals and human leptospirosis. J Venomous Anim Toxins Incl Trop Dis 17:119–129
66. Goarant C (2016) Leptospirosis: risk factors and management challenges in developing countries. Research and reports in tropical medicine 7:49–62. https://doi.org/10.2147/rrtm.S102543
67. Maas M, De Vries A, Reusken C, Buijs J, Goris M, Hartskeerl R, Ahmed A, Van Tulden P, Swart A, Pijnacker R, Koene M, Lundkvist A, Heyman P, Rockx B, Van Der Giessen J (2018) Prevalence of *Leptospira* spp. and Seoul hantavirus in brown rats (*Rattus norvegicus*) in four regions in the Netherlands, 2011-2015. Infect Ecol Epidemiol 8(1):1490135. https://doi.org/10.1080/20008686.2018.1490135
68. Kamath R, Swain S, Pattanshetty S, Nair NS (2014) Studying risk factors associated with human leptospirosis. J Global Infect Dis 6(1):3–9. https://doi.org/10.4103/0974-777x.127941
69. Levett PN (2001) Leptospirosis. J Clin Microbiol Rev 14(2):296–326. https://doi.org/10.1128/CMR.14.2.296-326.2001%
70. Ahmed N, Devi SM, Valverde Mde L, Vijayachari P, Machang'u RS, Ellis WA, Hartskeerl RA (2006) Multilocus sequence typing method for identification and genotypic classification of

pathogenic *Leptospira* species. Ann Clin Microbiol Antimicrob 5:28. https://doi.org/10.1186/1476-0711-5-28
71. Loan HK, Van Cuong N, Takhampunya R, Kiet BT, Campbell J, Them LN, Bryant JE, Tippayachai B, Van Hoang N, Morand S, Hien VB, Carrique-Mas JJ (2015) How important are rats as vectors of leptospirosis in the Mekong Delta of Vietnam? Vector Borne Zoonotic Dis 15(1):56–64. https://doi.org/10.1089/vbz.2014.1613
72. Berman SJ, Irving GS, Kundin WD, Gunning JJ, Watten RH (1973) Epidemiology of the acute fevers of unknown origin in South Vietnam: effect of laboratory support upon clinical diagnosis. Am J Trop Med Hyg 22(6):796–801
73. Le Thi Thanh Xuan, Nguyen Thi Binh Ngoc, Hoang Thi Thu Ha, Tai LT (2015) Some epidemiological characteristics of Leptospirosis in Vietnam during the period from 2002 to 2011. The Vietnam J Pre Med 166:358–362
74. Pozio E (2007) World distribution of *Trichinella* spp. infections in animals and humans. Vet Parasitol 149(1–2):3–21. https://doi.org/10.1016/j.vetpar.2007.07.002
75. Murrell KD, Pozio E (2011) Worldwide occurrence and impact of human trichinellosis, 1986-2009. Emerg Infect Dis 17(12):2194–2202. https://doi.org/10.3201/eid1712.110896
76. Dupouy-Camet J, Kociecka W, Bruschi F, Bolas-Fernandez F, Pozio E (2002) Opinion on the diagnosis and treatment of human trichinellosis. Expert Opin Pharmacother 3(8):1117–1130. https://doi.org/10.1517/14656566.3.8.1117
77. Odermatt P, Lv S, Sayasone S (2010) Less common parasitic infections in Southeast Asia that can produce outbreaks. Adv Parasitol 72:409–435. https://doi.org/10.1016/s0065-308x(10)72013-3
78. Pozio E, Hoberg E, La Rosa G, Zarlenga DS (2009) Molecular taxonomy, phylogeny and biogeography of nematodes belonging to the Trichinella genus. Infect Genet Evol 9(4):606–616. https://doi.org/10.1016/j.meegid.2009.03.003
79. Barennes H, Sayasone S, Odermatt P, De Bruyne A, Hongsakhone S, Newton PN, Vongphrachanh P, Martinez-Aussel B, Strobel M, Dupouy-Camet JJT (2008) A major trichinellosis outbreak suggesting a high endemicity of *Trichinella* infection in northern Laos. Am J Trop Med Hyg 78(1):40–44
80. Van De N, Thi Nga V, Dorny P, Vu Trung N, Ngoc Minh P, Trung Dung D, Pozio E (2015) Trichinellosis in Vietnam. Am J Trop Med Hyg 92(6):1265–1270. https://doi.org/10.4269/ajtmh.14-0570
81. Blanc F, Collomb H, Armengaud M (1956) Study of six cases of trichinosis. Bull Mem Soc Med Hop Paris 57(4):201–261
82. Del Brutto OH, Garcia HH (2015) Taenia solium Cysticercosis–the lessons of history. J Neurol Sci 359(1–2):392–395. https://doi.org/10.1016/j.jns.2015.08.011
83. Dung VT (2014) Bệnh sán dải heo (Taenia solium và taenia asiatica hay Taenia solium và pork tapeworm). http://www.impehcm.org.vn/noi-dung/kham-benh-giun-san/benh-san-dai-heo-taenia-solium-va-taenia-asiatica-hay-taenia-solium-va-pork-tapeworm.html
84. Ng-Nguyen D, Stevenson MA, Traub RJ (2017) A systematic review of taeniasis, cysticercosis and trichinellosis in Vietnam. Parasit Vectors 10(1):150. https://doi.org/10.1186/s13071-017-2085-9
85. O'Neal SE, Moyano LM, Ayvar V, Rodriguez S, Gavidia C, Wilkins PP, Gilman RH, Garcia HH, Gonzalez AE (2014) Ring-screening to control endemic transmission of Taenia solium. PLoS Negl Trop Dis 8(9):e3125. https://doi.org/10.1371/journal.pntd.0003125
86. Van De N, Le TH, Lien PT, Eom KS (2014) Current status of taeniasis and cysticercosis in Vietnam. Korean J Parasitol 52(2):125–129. https://doi.org/10.3347/kjp.2014.52.2.125
87. Shah J, Shahidullah A (2018) Ascaris lumbricoides: a startling discovery during screening colonoscopy. Case Rep Gastroenterol 12(2):224–229
88. Leles D, Gardner SL, Reinhard K, Iñiguez A, Araujo AJP (2012) Are Ascaris lumbricoides and Ascaris suum a single species? Vectors 5(1):42
89. Institut Pasteur in Ho Chi Minh (2014) City Các bệnh do giun đũa/Ascaridosis. http://www.pasteurhcm.gov.vn/news/cac-benh-do-giun-dua-111.html. Accessed 10/08/2018
90. Centers for Disease Control and Prevention (2018) Ascariasis. https://www.cdc.gov/parasites/ascariasis/index.html. Accessed 10/08/2018
91. Yoshida A, Hombu A, Wang Z, Maruyama H (2016) Larva migrans syndrome caused by Toxocara and Ascaris roundworm infections in Japanese patients. Eur J Clin Microbiol Infect Dis 35(9):1521–1529. https://doi.org/10.1007/s10096-016-2693-x
92. van Soelen N, Mandalakas AM, Kirchner HL, Walzl G, Grewal HM, Jacobsen M, Hesseling AC (2012) Effect of Ascaris lumbricoides specific IgE on tuberculin skin test responses in children in a high-burden setting: a cross-sectional community-based study. BMC Infect Dis 12:211. https://doi.org/10.1186/1471-2334-12-211
93. van der Hoek W, De NV, Konradsen F, Cam PD, Hoa NT, Toan ND, Cong le D (2003) Current status of soil-transmitted helminths in Vietnam. Southeast Asian J Trop Med Public Health 34(Suppl 1):1–11
94. Organization WH (2015) World Health Organization, Food Safety: What you should know
95. Murphy FA (1999) The threat posed by the global emergence of livestock, food-borne, and zoonotic pathogens. Ann N Y Acad Sci 894:20–27
96. McCarthy J, Moore TA (2000) Emerging helminth zoonoses. Int J Parasitol 30(12–13):1351–1360
97. Slifko TR, Smith HV, Rose JB (2000) Emerging parasite zoonoses associated with water and food. Int J Parasitol 30(12–13):1379–1393
98. Wikipedia (2018) Tiết canh- Raw blood pudding. https://en.wikipedia.org/wiki/Ti%E1%BA%BFt_canh. Accessed 15/08/2018
99. Huong VTL (2014) Raw pig blood consumption and potential risk for *Streptococcus suis* infection, Vietnam - Volume 20, Number 11—November 2014 - Emerging Infectious Diseases journal - CDC. 20
100. VAPM (2016) Epidemiological characteristics of *Streptococcus suis* disease in Hanoi city in 2015 (In Vietnamese: Một số đặc điểm dịch tễ học bệnh liên cầu lợn tại Hà Nội, 2015). http://www.tapchiyhocduphong.vn/tap-chi-y-hoc-du-phong/2016/15/81E204F5/mot-so-dac-diem-dich-te-hoc-benh-lien-cau-lon-tai-ha-noi-2015/
101. News TN (2014) Swine bacteria kills man in northern Vietnam. http://www.thanhniennews.com/health/swine-bacteria-kills-man-in-northern-vietnam-23965.html
102. Naicker PR (2011) The impact of climate change and other factors on zoonotic diseases. Archives of Clinical Microbiology 2. http://www.acmicrob.com/microbiology/the-impact-of-climate-change-and-otherfactors-on-zoonotic-diseases.php?aid=220. Accessed 16/08/2018
103. Mills LC (2018) Characterizing environmental factors influencing zoonotic disease reservoirs using meta-parasite prevalence
104. Cardenas R, Sandoval CM, Rodriguez-Morales AJ, Vivas P (2008) Zoonoses and climate variability. Ann N Y Acad Sci 1149:326–330. https://doi.org/10.1196/annals.1428.094
105. Zinsstag J, Crump L, Schelling E, Hattendorf J, Maidane YO, Ali KO, Muhummed A, Umer AA, Aliyi F, Nooh F, Abdikadir MI, Ali SM, Hartinger S, Mausezahl D, de White MBG, Cordon-Rosales C, Castillo DA, McCracken J, Abakar F, Cercamondi C, Emmenegger S, Maier E, Karanja S, Bolon I, de Castaneda RR, Bonfoh B, Tschopp R, Probst-Hensch N, Cisse G (2018) Climate

change and one health. FEMS Microbiol Lett 365(11). https://doi.org/10.1093/femsle/fny085
106. Caminade C, McIntyre KM, Jones AE (2018) Impact of recent and future climate change on vector-borne diseases. Ann N Y Acad Sci. https://doi.org/10.1111/nyas.13950
107. Wu X, Lu Y, Zhou S, Chen L, Xu B (2016) Impact of climate change on human infectious diseases: empirical evidence and human adaptation. Environ Int 86:14–23. https://doi.org/10.1016/j.envint.2015.09.007
108. Food safety (2017) Scientists warn about Vietnam pig's blood delicacy.. https://foodsafety.suencs.com/?p=46672. Accessed 15/08/2018
109. Akinade AJ (2015) Zoonotic diseases prevention and control: the role of awareness and educational programmes (thesis)