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Review Article

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A Review on Confronting Zoonoses: The Role of Veterinarian and Physician

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Abstract

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and humans. The organisms causing zoonoses include viruses, bacteria, fungi, protozoa and other parasites, with both domestic and wild animals acting as reservoirs for the pathogens. Zoonoses comprise interaction between at least three species: one pathogen and two host species (animals and humans). They can be transmitted directly by contact with infected animals (e.g. rabies, through bite), via contaminated environment (e.g., anthrax) and via food (e.g., campylobacteriosis) or indirectly via vectors, such as mosquitoes or ticks (e.g., West Nile fever and Lyme disease, respectively).There are many factors influencing the zoonoses diseases. The convergence model organizes the potential factors into a series of broad domains that include: socioeconomic and biological factors; ecological and environmental factors; and the interface of domestic animals, wildlife, and human factors. Zoonoses have affected human health throughout times, and wildlife and domestic animals have always played a role for the transmission of the disease which is public health threats worldwide. So success in the preventing and controlling of major zoonoses depend on the capability to mobilize resources in different sectors and on coordination and intersectoral approaches, especially, between national (or international) veterinary and public health services.

Keywords: Physician; Public health; Risk factors; Veterinarian; Zoonoses

Introduction

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and humans [1]. Worldwide, an estimated 60–70% of emerging infectious diseases in humans are zoonoses and large proportions originate from wildlife. They can be transmitted directly by contact with animal (example, rabies, through bite), via contaminated environment (example, anthrax) and via food (e.g. campylobacteriosis) or indirectly via vectors, such as mosquitoes or ticks (West Nile fever, and Lyme diseases, respectively) [2].

Zoonotic disease organisms include that are endemic in human population or enzootic in animal populations with frequent cross-species transmission to people. The greatest burden on human health and livelihood, amounting to about one billion cases of illness and millions of death every year, is caused by endemic zoonoses that are persistent regional health problems around the world [3]. The organisms causing zoonoses include viruses, bacteria, fungi, protozoa and other parasites, with both domestic and wild animals acting as reservoirs for the pathogens. The diseases cause in humans range from mild and self-limiting (e.g., most cases of toxoplasmosis) to fatal (e.g., Ebola hemorrhagic fever). In United Kingdom food is thought to be the most common source of zoonotic diseases [4]. Because these diseases come from animals, prevention and control strategies need to be innovative and require the combined efforts of many fields [5].

Zoonoses with domestic and wildlife reservoir represent a large spectrum of transmission modes. The dynamics of zoonotic disease transmission are deeply embedded in the ecology and evolutionary biology of their hosts. Many zoonoses with a wildlife origin are spread through insect vectors. For vector-borne zoonoses the ecology is complicated because of the ecology of numerous other vectors and reservoir host species which can change transmission dynamics [6].

The critical factors, influencing zoonoses consist of microbial adaptation and change; host susceptibility; climate and weather; changing ecosystem, demographic, and population including issues of wildlife and exotic animals; economic development and land use; international trade and travel; technology and industry; reduction in animal and public health services or infrastructures; war and dislocation are factors influencing zoonoses [7]. Since zoonoses can infect both animals and humans, the medical and veterinary communities should work closely together in clinic, public health, and research settings. For example, closer collaboration is needed between veterinarians, physicians, and public health professionals in three areas: individual health, population health, and comparative medicine research [5]. In the individual health setting, assessing the potential for zoonotic disease transmission from animals to humans should include input from both physicians and veterinarians, especially for patients at high risk such as those who are immunocompromised. In population health, zoonotic disease threats should be addressed through surveillance systems that include domestic and wild animal, and human populations, which would help lead to effective control measures [5]. Therefore, this review is conducted to provide more comprehensive and stimulating overview regarding zoonoses, discus the role of veterinarians and physician in confronting zoonoses, and discus the importance of multi-sector partnership in controlling zoonoses.

General overview of confronting zoonoses

Historical aspects of zoonoses: By studying the surviving documents describing surveillance and methods of control in the distant past the history of fight against zoonoses diseases can be retraced. Prior

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to 20 century, the best known zoonoses were, amongst others, rabies, anthrax, glanders, tuberculosis, plague, yellow fever, influenza, and other certain zoonotic parasitic diseases. As analysis of historical events yield a numbers of lessons as to the positive and negative influence of past theories regarding the etiology, contagiousness and control of these diseases [8].

Zoonoses have affected human health throughout times, and wildlife and domestic animals have always played a role. For example, bubonic plague, a bacterial disease for which rats and fleas play a central role in transmission, has caused substantial illness and death around the world since ancient times [9]. A possible epidemic of bubonic plague was described in the Old Tesment, in the First Book of Samuel. The so-called Black Death emerged in 14th century and caused vast losses throughout Asia, Africa, and Europe. The epidemic, which originated in the Far East, killed approximately one third of Europe's population. However, bubonic plague still occurs in Asia, Africa, and the Americas, and the World Health Organization annually reports 1,000-3,009 cases. In the western United States, acquisition of plague in humans is linked to companion animals infested with *Yersinia pest*-carrying fleas in areas of epidemic sylvatic disease [10]. Rabies was described in Mesopotamia, in hunting dogs, as early as 2,300 BC. Recognizable descriptions of rabies can also be traced back to early Chinese, Egyptian, Greek, and Roman records [8]. In Europe in the medieval age, rabies occurred in both domestic animals and wildlife. Rabid foxes, wolves, badgers, and bears have been described in the literature as well as in the figurative art [11].

Ancient account and modern hypotheses suggest that Alexander the Great, who died in Babylon in 323 BC, died of encephalitis caused by West Nile virus, a virus that has a wide wild bird reservoir. Marr and Calisher reported that as Alexander entered Babylon, a flock of ravens exhibiting unusual behaviour died at his feet [12].

Magnitude of zoonotic disease

Of the new identified zoonotic pathogen, most are viruses, in particular, RNA viruses. For example it is estimated that the ocean alone contain somewhere around 4×10^{30} viruses. This number is greater than the number of stars in the observable universe. Enormous numbers of viral particles can exist on land. For example, one duck can excrete billions of avian influenza (AI) virus particles. Given the enormity of the numbers of emerging viruses as well as the growing challenges of drug-resistant bacteria, the medical and veterinary communities must work together to better understand and contain them [13].

Transmission modes of zoonoses disease

Zoonoses with domestic and wildlife reservoir represent a large spectrum of transmission modes. The dynamics of zoonotic disease transmission are deeply embedded in the ecology and evolutionary biology of their hosts. Zoonoses comprise interaction between at least three species: one pathogen and two host species, with, people and another animal species acting as the reservoir of the infection. They can be transmitted directly by contact with animals (e.g. rabies, through bite), via contaminated environment (e.g., anthrax) and via food (e.g. campylobacteriosis) or indirectly via vectors, such as mosquitoes or ticks (e.g. West Nile fever and Lyme disease, respectively). Increasing demands for food due to an expanding global population has led to a substantial susceptibility of our population to zoonoses [14].

In the United Kingdom, food is thought to be the most common source of zoonotic diseases. The volume of consumption of wildlife products for food is at least an order of magnitude lower than it is for domestic livestock. However, human being–animal contact associated with hunting, preparation, and consumption of wild animals has led to transmission of notable diseases. Such diseases include HIV/AIDS, which was linked to the butchering of hunted chimpanzees, SARS, which emerged in wildlife market and workers in southern China, and Ebola hemorrhagic fever linked to the hunting or handling of infected great apes or other wild animals. All these disease transmissions are examples of organisms or pathogens exploiting new host opportunities resulting from human behaviour [4].

Many zoonoses with a wildlife origin are spread through insect vectors. For vector-borne zoonoses the ecology is complicated because the ecology of numerous other vector and reservoir host species can change transmission dynamics [6]. For example, mosquitoes are well known vectors of several animal zoonoses, such as Rift Valley fever, equine encephalitis, Japanese encephalitis. *Yersinia pestis* can be spread by fleas, *Bacillus anthracic* spores by flies and Leishmania by sand flies, whereas ticks are essential in the spread of *Ehrlichia/Anaplasma*/ a genus of microorganisms (family *Anaplasmataceae*), including *A. marginale*, the etiologic agent of Anaplasmosis [15].

A good example of zoonotic agent with many different transmission modes is *Salmonella*. Reptile-associated salmonellosis is well- described phenomena, especially among children. Keeping reptile and other exotic pet animals as pets presents a public health problem; such animals are carriers of salmonellosis [12] and thereby can infect humans directly or indirectly. In 1987, a nationwide outbreak of *S.* Typhimurium infection was traced to chocolate bars that had been contaminated by wild birds in the factory. In 1999, a water-borne outbreak of *S.* Typhimurium infection was linked to a dead seagull that had contaminated a reservoir water source from which the water was used untreated [16,17].

Bacillus anthracic is a primary disease of herbivores, and transmitted from animals to humans by various modes. The spores formed by the bacteria are very resistant and have been found to remain dormant and viable in nature for >100 years [18]. Human can be infected by eating meat from infected carcasses or drinking contaminated water, through the skin by contact with infected materials or by insect bites, and through lungs by inhaling spores. Although livestock anthrax is declining in many parts of the world, the disease remains enzootic in many national parks, for example, in southern Africa and North America. Anthrax in animals represents a persistent risk for surrounding livestock and public health [19].

Wildlife translocation, in which humans move wildlife from one geographic site to another, is a common conservation tool but also a practice that has facilitated the emergence of zoonosis. In the United State of America, the translocation of raccoons from south east United State to the Mid-Atlantic state and New England produced a new enzootic foci for raccoon rabies. Rabies has also been translocated with foxes and coyotes moved for sporting reasons. In addition, Multilocular echinococcosis, caused by small tapeworm *Echinococcus multilocularis*, has also been influenced by the translocation of animals. The main hosts are canids especially, foxes and the intermediate hosts are small rodents. Humans can become accidental intermediate hosts, by ingesting eggs. Multilocular echinococcosis occurs in large parts of the Northern Hemisphere. In 1999, *E. multilocularis* was detected for the first time in Norway, in the archipelago of Spitzbergen [17,20], The parasite most probably spread from Russia, by natural movement of the main host, the sibling vole, had previously been translocated to Spitsbergen, most likely through imported animal feed [21]. In Copenhagen, Denmark, in 2000, *E. multilocularis* was detected in a traffic-killed red fox. The theory is that the fox had travelled by train from central Europe, where the disease is endemic [11].

Bovine tuberculosis caused by *Mycobacterium bovis* is another zoonosis in which both natural and anthropogenic movement of animals has influenced the disease. This zoonosis is emerging in wildlife in many parts of the world, and wildlife can represent a source of infection for domestic animals and humans. Bovine tuberculosis was probably introduced into Africa with imported cattle during the colonial era and there after spread and become endemic in wildlife [22]. In Ireland and Great Britain, badgers maintain the infection, whereas the brush tail possum constitutes a main wild life reservoir in New Zealand. In parts of Michigan, bovine tuberculosis is endemic among white-tailed deer, whereas in Europe, both wild boars and various deer species can be reservoir of the pathogen. The natural movement of these reservoir animals increases the spread of the disease to domestic animals and thereby its public health impact [23].

Factors influencing zoonoses diseases

Microbial adaptation: Microbes are specially component at adaptation and genetic change under selective pressure for survival and replication. The remarkable adaptation of microbes to become resistant to anti-microbial product is seen in both humans and animals populations and is linked between the two [24]. Transmission of adaptive of genetically changed microorganisms from animals to humans, either directly or indirectly through domestic animals, may occurs in many ways. In this respect an international wildlife trade, often illegal, in which wild animals end up in live-animal markets, restaurants, and farms, is important because such practice increase the proximity between wildlife, domestic animals, and humans [25].

Severe acute respiratory syndrome (SARS) is current example of likely microbial adaptation. It is caused by SARS-associated corona virus, and is believed to have emerged in Guangdong, China, in November 2002. SARS was first reported in Asia in February 2003, and over the next few months, the illness spread to a global epidemic before it was contained. Accordingly to the World Health Organization, 8,098 cases, including 774 fatalities, have occurred during this epidemic. The virus has an unknown reservoir, but wildlife is a likely source of infection. Natural infection has been demonstrated in palm civet cats in markets and also in raccoon dogs, rats, and other animals indigenous to the area where SARS likely originated [26].

Genetic change is typically influence the epidemiology of some disease. A natural infections with influenza A virus have been reported in variety of animal species, including birds, humans, pigs, horses, and sea mammals, and its main reservoir seems to be wild waterfowl, especially ducks. It has two main surface antigens; hem agglutinin with 15 subtypes and neuraminidase with 9 serotypes. All these subtypes, in most combinations, have been isolated from birds, whereas few combinations have been found in mammals. “New” pandemic strains most certainly emerged after assortment of genes of viruses of avian and human origin in permissive host [13]. H_5N_1 strains of highly pathogenic avian influenza that caused a severe outbreak in poultry in Southeast Asia in 2004 [27] demonstrated its capacity to infect humans; 39 cases, 28 of them fatal, were officially reported [28].

Climate and weather change: Although the spread of disease is multi causal, global climate change can influences host defence, vector, pathogens, and habitats. This leads to the movement of pathogens, vectors, and animals hosts. Ross river virus is mosquito-borne disease found through Australia, and outbreaks are sensitive to excessive rainfall events. Malaria and plague fever are two other mosquito-borne diseases that are likely to spread dramatically with global warming. In addition, leptospirosis and Rift Valley fever are zoonotic pathogens sensitive to weather and climate change and they been found in a variety of epidemics worldwide over the last decade [29].

During the summer of 2003, an outbreak of monkey pox occurred in the United States with 37 confirmed human cases [30]. Monkey pox is rare zoonosis caused by a poxvirus that typically occurs in Africa. It was first found in monkey in 1958 and later on other animals, especially rodents. The African squirrel is probably the natural host. Transmission to humans occurs by contact with infected animals or body fluids. Thus, the transportation, sale, or distribution of animals, or the release of animals into the environment, can represent a risk for spread of this zoonosis disease [11].

Human behaviour and demographic factors: Human behaviour and demographic factors can influence zoonosis with wildlife reservoirs. The interaction of demographic trends in the latter parts of the 20th century and growth of population with animal and animal products causes the appearance of emerging re-emerging zoonoses [31]. Hiking, camping, and hunting are activities that may represent the risk factors for acquiring certain zoonoses with wildlife reservoir, e.g., tick-borne zoonoses and tularemia. Eating habits can also play a role. For example, eating meat from exotic animals such as bear increases the risk of acquiring trichinellosis [32]. AIDS represents a disease in which demographic factors and human behaviour have contributed to its development into a global public health problem. The origin of HIV, the virus causing AIDS, is still a matter of controversy, but HIV likely spread to humans from nonhuman primate in West Africa [33].

Over-population: As human populations encroach upon wild habitat, people come into contact with more wild animals and diseases they carry. Ebola and AIDS probably jumped from chimpanzees to humans as populations pressure increased, the consumption of bush meat, exposing people to infected blood and tissue during butchering. Wildlife health is impacted, too, as native species are exposed for the first time to human and domestic animal diseases [4].

Deforestation can also force wildlife reservoirs of zoonotic diseases into closing proximity with humans. The sudden emergence of Nipha virus disease in pigs and humans in Southeast Asia in the late 1990s may have been caused by rapid deforestation to clear land for forming timber production. The natural reservoir for Nipha virus appears to be fruit-eating flying foes (bats in the genus *Pteropus*). As deforestation reduced their native food sources, flying fox population were thrust into closer contact with commercial fruit orchards and fruit trees on pig farms, where virus spread to pigs and then to humans [34].

The movement of pathogens, vectors, and animal hosts: The movement of pathogens, vectors, and animal hosts can influence the occurrence of zoonoses with wildlife reservoir. These movements can, for example, occur through human travel and trade, by natural movement of animals including migratory birds, and by anthropogenic movement of animals. Thus infectious agents can be transported to the farthest land in less time than it takes most diseases to incubate. The movement of infected wild and domestic animal is an important factor in the appearance of rabies in new location. The appearance of West Nile virus infection in New York in 1999, and the subsequent spread within the United States, is an example of introducing and establishment of pathogen that apparently originated in the Middle East [35].

Surveys of human pathogens

The survey data showed that those pathogens regarded as emerging and re-emerging were more likely to be zoonotic than those that are not. Even if a pathogen is capable of infecting and causing disease in humans, most zoonotic pathogens are not highly transmissible within human populations and do not cause major epidemics [36,37]. Humans are affected by an impressive diversity of pathogens; 1,415 pathogenic species of viruses, bacteria, fungi, protozoa, and helminthes are currently recognized. Of the 1,415 human pathogen species, 868 (61%) are known to be zoonotic. Likewise of this total, 177 (13%) pathogen species are considered emerging or re-emerging. Of all the pathogen species, 211 are viruses or prions, including 77 (37%) regarded as emerging or re-emerging. For bacteria, the counts were 539 and 54 (10%), respectively; for fungi, 318 and 22 (7%), respectively; protozoa, 58 and 14 (25%), respectively; and for helminthes, 289 and 10 (3%), respectively [38].

In comparison, 177 of the emerging or re-emerging pathogens, 130 (73%) are known to be zoonotic. This corresponds to confirm the expectation that zoonotic pathogens are disproportionately likely to be associated with emerging and re-emerging infectious diseases. This pattern varies somewhat across the different pathogen groups: for bacteria and fungi the association is strongest; for viruses and protozoa, no obvious association was found, and for helminthes (which are almost all zoonotic but very rarely emerging or re-emerging) [38].

The magnitude of the problem of zoonoses illustrates why the efforts of medicine, veterinary medicine, and public need to overlap. Taylor and others identified 1,415 infectious agents and found that 868 (61%) could be transmitted between animals and humans [39].They found that zoonotic diseases were twice more likely to be associated with emerging or newly discovered infections than non-zoonotic pathogens and that viruses and protozoa were the zoonotic pathogens most likely to emerge. RNA viruses, in particular, have been identified as highly likely to emerge [40]. These agents include WNV, avian influenza virus, Hantavirus, and SARS associated corona virus. These types of surveillance systems should be continued and expanded to include other series zoonotic diseases such as plague and tularemia [38].

The role of physicians and veterinarians

Since zoonoses can infect both animals and humans, the medical and veterinary communities should work closely together in clinical, public health, and research settings. In the clinical setting, input from both professions would improve assessments of the risk-benefit ratios of pet ownership, particularly for pet owners who are immunocompromised. In public health, human and animal disease surveillance systems are important in tracking and controlling zoonoses The bond between humans and animals has been recognized for many years, and pet ownership has been associated with both emotional and health benefits. However, pet ownership may also pose health risks through the zoonotic transmission of infectious diseases, especially, compromised individuals [41].

Since human medicine often does not delve deeply into the role of animals in the transmission of zoonotic disease agents and veterinary medicine does not cover the clinical aspects of human disease, zoonotic disease control requires involvement of both physicians and veterinarians [42]. It is especially important that both veterinarians and physicians are involved in the control of zoonotic disease because the latter do not usually consider the role of animals in the transmission of disease and the former do not receive extensive training on clinical aspects of human disease [43].

The links between the two professionals on broader scale to foster a broader consensus about zoonotic disease risks and prevention should be encouraged. Veterinarian are knowledgeable of potential risks of zoonotic diseases and how to minimize them, placing them in an ideal position to provide pet owners with reliable information about preventing and to recommend appropriately-timed preventive medication for pets to reduce risks [44].

However, success in the preventing and controlling of major zoonoses depend on the capability to mobilize resources in different sectors and on coordination and intersectoral approaches, especially, between national (or international) veterinary and public health services [45]. So closer collaboration between veterinarians, physicians and public health professionals is needed and veterinary and medical communities should work closely together in clinical, public health and research setting. There is a need to work with state officials during zoonotic outbreaks as well as with local public health officials [43].

Finally, among the most important targets to meet is building robust and well-governed public health, and animal health system complaint with the WHO and OIE international standards. Such strategy should provide integrated and specialized training at national and regional level to sectoral recognized for their importance and weakness. Additional targets consist of emphasizing the importance of cross-sectoral collaboration and coordination, together with motivating trainees to abandon traditional behaviours and better inform decision makers in order to obtain the necessary political, legal and financial support. Veterinarians and physicians need to work with state officials during zoonotic outbreaks as well as local public officials [46].

Role of multi-sector partnership in controlling zoonoses

Zoonoses are diseases that can be transmitted from wild and domestic animals to humans and are public health threats worldwide. So the implementation of zoonoses control program must rely on multidisciplinary sources for data on epidemiology, socio-economic impact and other fundamental aspects of zoonoses. Closer collaboration is required among health institutions, public authorities, diagnostic facilities, the medical sector and veterinary services. Veterinary public health has been defined as one part of public health action which is committed to the protection and improvement of human health through application of the capabilities, knowledge, and profession as sources of veterinary services [47]. Because these diseases come from animals, prevention and control strategies need to be innovative and require the combined efforts of many fields. For example, closer collaborations are needed between veterinarians, physicians, and public health professionals in 3 areas: individual health, population health, and comparative medicine research [5].

Individual health collaborations: At the individual health level, zoonotic diseases are a concern for all who live or work with animals. This risk is especially problematic for persons, such as companion animal owners, who are immunocompromised. Grant and Olsen found that physicians are generally not comfortable discussing the role of animals in the transmission of zoonoses and would prefer that veterinarians play a role. However, most patients do not view veterinarians as a source of information for human health. The authors found that only 21% of HIV patients asked their veterinarians about the health risks of pet ownership [43].

Occupational risks for exposure to zoonotic diseases are a concern for persons such as farmers, meatpackers and pet shop employees who work with animals. For example, *Streptococcus suis* can cause meningitis or occasionally fulminant sepsis in pig farmers [48]. *Campylobacter* infection is an occupational risk for packers in poultry factories, and *Streptobacillus moniliformis* can be an occupational risk for pet shop employees. These examples illustrate that living and working with animals can impact human health at the individual level [49].

Since companion animal ownership has psychologic and physiologic benefits, type of collaboration and cooperation between the two professions would be invaluable to patients. The veterinarian would provide regular check-ups to the companion animal to ensure that its health status is closely monitored. In the occupational setting, regular veterinary monitoring of all involved animals' health may not be possible; however, if a worker were immunocompromised, then a careful assessment should be made about his or her continuing that line of work. Joint medical and veterinary medical workshops on zoonotic risks to human health could help forge ties and facilitate opportunities to establish these types of collaborative effort [50].

Population health collaborations: At the population level, zoonotic pathogens cause disease outbreak (food-borne, water-borne, and arthropod-borne). Recognizing whether human and animal outbreaks were simultaneous would provide important information for identifying the causative pathogens and developing control strategies communications between the veterinarians, public health officials, and physicians who were involved in the outbreak response at the local level. As an emergency, short-term measure, veterinarians could have expressed their concerns directly to the hospital epidemiologists in the area to be on the lookout for a possible human impact from an unknown disease that was causing widespread severe neurologic symptoms and death in wild birds. Such rapid, direct communication between veterinarians and physician epidemiologists could be particularly important in states in which local public health agencies either do not exist or are not involved in zoonotic disease reporting or investigation [51].

The magnitude of the problem of zoonoses illustrates why the efforts of medicine, veterinary medicine, and public health need to overlap. Taylor and others identified 1,415 infectious agents and found that 868 (61%) could be transmitted between animals and humans [37]. They found that zoonotic diseases were twice more likely to be associated with emerging or newly discovered infections thannon-zoonotic pathogens and that viruses and protozoa were the zoonotic pathogens most likely to emerge. RNA viruses, in particular, have been identified as highly likely to emerge. These agents include WNV, avian influenza virus, Hantavirus, and severe acute respiratory syndrome-associated coronavirus [36].

Animal disease reporting and oversight are split between different agencies in some states. This is the situation at the federal level and has prompted a recent National Academy of Sciences report to recommend that a federal-level, centralized coordinating mechanism be established to improve collaboration and cooperation among all the players in animal health oversight, including industry and local, state, and federal agencies [52].

A similar mechanism for improving communication and collaboration across state agencies, such as between state animal health and public health veterinarians, would be important since evidence suggests that veterinarians preferentially report to more "animal-centric" state agencies. Joint surveillance of animal and human zoonotic disease outbreaks is already reaping benefits worldwide. For example, recognition of the first human case of H5N1 avian influenza in Hong Kong in 1997 was facilitated by the surveillance of ducks, geese, and chickens in southern China during the preceding decades [53].

In addition to on-going joint surveillance activities, researchers should collaborate in applied public health studies. For example, physician and veterinarian teams could conduct sero-surveys of humans who live and work near high-risk animal populations to assess their risk of acquiring zoonoses. Long-term surveillance studies could be conducted on humans who are exposed to deer and elk, which are at risk of acquiring chronic wasting disease in disease-endemic regions of Colorado, Wyoming, and Nebraska [54]. Surveillance studies on the role of vaccinated and unvaccinated horses in the amplification of WNV to humans would help improve our understanding of the epidemiology of virus activity [55].

Comparative medicine research collaborations: The need for physicians and veterinarians to work together to control zoonoses extends beyond the individual and population health settings and should include collaborations in comparative medicine research. Comparative medicine is the study of the anatomic, physiologic, and pathophysiologic processes across species, including humans. Considerable attention is paid to infectious diseases, specifically the study of host-agent interactions [56].

The field has an illustrious history. In 1893, Theobald Smith, a physician, and F.L. Kilbourne, a veterinarian, published a paper establishing that an infectious agent, *Babesia bigemina*, the cause of cattle fever, was transmitted by an arthropod vector. Their seminal work helped set the stage for Walter Reed's discovery of yellow fever transmission [56].

Another physician-veterinarian team, Drs. Rolf Zinkernagel and Peter C. Doherty, won the 1996 Nobel Prize in physiology or medicine for their discovery of how the immune system distinguishes normal cells from virus-infected cells. These two examples illustrate that medicine and veterinary medicine are complementary; they are synergistic in generating new scientific insights across species. In essence, the two disciplines epitomize the philosophy of comparative medicine. And yet, as societies' needs grow to have scientists work together to understand and control emerging zoonoses, evidence suggests that the next generation of medical and veterinary medical scientists are not collaborating with each other. Biomedical and comparative medicine research is losing its appeal as a career among physicians and veterinarians [57].

On the physician side, the decline in physician-scientists is evidenced by several trends. First, from 1970 to 1997, the number of physician-scientists obtaining National Institutes of Health (NIH) support has been essentially flat and shrinking in proportion to doctoral recipients who seek and obtain funding [58]. Second, from 1994 to 1997, the number of first-time physician-scientists seeking NIH funds dropped by 31%, and the percentage of medical school graduates interested in research careers fell from 14% in 1989 to 10% in 1996. Medical school faculties now comprise 25% fewer physician-scientists than 20 years ago [59]. Reasons for the lack of interest in research are similar for both medical and veterinary students: an emphasis on clinical care, educational debt, and a lack of mentors and research opportunities. Medical schools now emphasize primary care and care for the underserved, and while certainly important, this shift in priorities has been at the expense of encouraging biomedical research careers [60].

Veterinary schools have shifted their focus from comparative medicine research and livestock medicine to companion animal medicine to meet societal demand. However, similar to the situation with medical schools, this shift has caused fewer numbers of veterinary students to pursue research careers. In addition, comparative medicine programs have been shifting from a research to service orientation that limits veterinarians' research involvement to being primarily caretakers for laboratory animals. This shift in comparative medicine orientation has discouraged many veterinary students from pursuing careers in research and hinders research on emerging zoonoses from diverse animal hosts [61].

Offering research grants to medical and veterinary medical research teams that are promoting collaborative projects on zoonoses are needed. Jointly funded integrated and comprehensive animal health research programs should be established to ensure that veterinary and medical scientists work together as collaborators domestically and internationally [52].

Conclusion and Recommendations

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and man. Worldwide, an estimated 60–70% of emerging infectious diseases in humans are zoonoses and large proportions originate from wildlife. Due to the behavioural and demographic change with the need of human, zoonoses risk also increases from time to time in the World. The effects of zoonoses are not limited to the health risk of both humans and animals, socio-economic effects are also major problems. If controlling zoonotic diseases is to be improved, greater communication and collaboration between veterinarians, physicians, and public health officials are needed. Generally, the effect of zoonoses increase from time to time and the magnitude to health problem in humans and animals population is increasing dramatically.

Therefore, based on the above conclusion the following recommendations are forwarded:

- Closer collaboration is required among health institutions, public authorities, diagnostic facility, the medical sectors and veterinary services.
- Veterinarians and physicians also need to work with state officials during zoonotic outbreaks as well as with local public health officials
- Jointly funded integrated and comprehensive animal health research programs should be established to ensure that veterinary and medical scientists work together as collaborators domestically and internationally.
- Improving communication and collaboration across state agencies, such as between state animal health and public health should be improved.
- Closer collaboration between veterinarians, physicians and public health professions should be encouraged.
- Federal level mechanisms to promote greater collaboration among all the players involved in animals and human's health should be carried out; similar mechanisms could also be considered in states.
- Encouraging more veterinary school graduates to pursue careers in research is critical if partnerships are to be developed.
- Medical, veterinary, and public health schools should offer courses on zoonotic risks to human health that integrate all the three perspectives.

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