Spring 2019

The One Health initiative: The intersection of human, animal, and environmental health

Mary Evelyn Pearsall

The One Health Initiative: The Intersection of Human, Animal, and Environmental Health

---

An Honors College Project Presented to

the Faculty of the Undergraduate

College of Science & Mathematics

James Madison University

---

by Mary Evelyn Igleheart Pearsall

Accepted by the faculty of the Biology Department, James Madison University, in partial fulfillment of the requirements for the Honors College.

FACULTY COMMITTEE:

____

Project Advisor: Dr. Pradeep Vasudevan Menon

____

Reader: Dr. Bisi Velayudhan

____

Reader: Dr. Louie Wurch

HONORS COLLEGE APPROVAL:

____

Bradley R. Newcomer, Ph.D.,
Dean, Honors College

PUBLIC PRESENTATION

This work is accepted for presentation, in part or in full, at the Honors Symposium on April 5th, 2019.

TABLE OF CONTENTS

TABLE OF FIGURES

ACKNOWLEDGEMENTS

I would like to especially thank my advisor for this project, Dr. Pradeep Vasudevan Menon and my committee members, Dr. Bisi Velayudhan and Dr. Louie Wurch. My committee has been an amazing source of patient guidance, enthusiastic encouragement, and useful critiques in this process. Their willingness to so generously give their time has been greatly appreciated. Lastly, I would like to thank my parents for their support and encouragement throughout my time working on the project.

ABSTRACT

The One Health concept is a global strategy for strengthening interdisciplinary collaborations among health care for humans, animals, and the environment. The purpose of this honors capstone project is to study the One Health Initiative and create a comprehensive thesis on what the initiative is and how it is relevant to different sectors of health. An overview of prevalent zoonotic diseases will be provided including how they are transmitted and their global relevance. Case studies on zoonotic diseases will be used in which the effectivity of a One Health approach can be analyzed. In addition, relevant sections on One Health and food safety and antimicrobial resistance will be included.

INTRODUCTION

The One Health concept is a global strategy for strengthening interdisciplinary collaborations among health care for humans, animals, and the environment. The necessity for this approach is especially important in the field of infectious disease, as 75% of all emerging infectious diseases are zoonotic (Chattu et al., 2018). Our interdependence with animals and their products is one of the most critical risk factors to our own health regarding infectious diseases. The mission statement of the One Health initiative dictates that human health, animal health, and ecological health are intimately linked. The statement goes on to describe that One Health seeks to "promote, improve, and defend the health and well-being of all species by enhancing cooperation and collaboration between physicians, veterinarians, other scientific health and environmental professionals" (AVMA, n.d.). This mission statement emphasizes the importance of collaboration across disciplines to solve global and local health issues. There is no way of ensuring human health without protecting the health of the environment along with domestic and wild animals. The intimate connections between the health of these three domains is a growing area of interest for many organizations and universities.

HISTORY

The concept of the One Health initiative has long been forming, but only recently gained any formal traction amongst the scientific community. Rudolph Virchow was a medical doctor who lived and worked in the mid-19th century. Virchow studied the links between human and veterinary medicine by studying *Trichinella spiralis*, a roundworm, in swine. Virchow coined the term "zoonosis" to indicate an infectious disease that is passed between humans and animals and was one of the first medical professionals to recognize the lack of divisions between realms of medicine (CDC, n.d.-c).

Years later, in 1947, the veterinary public health division was established at the CDC by Dr. James H. Steele, an important step in facilitating growth of the One Health concept. In 2004 the Wildlife Conservation Society held a conference at Rockefeller University in which scientists met to discuss the movement of diseases among humans, animals, and wildlife. The result of this conference was the production of 12 Manhattan Principles related to building interdisciplinary bridges (CDC, n.d.-c). These principles focus on recognizing the implications of zoonotic disease, applying interdisciplinary practices, and investing in opportunities to strengthen the One Health concept.

In 2007, the American Medical Association passed a One Health resolution with similar goals (CDC, n.d.-c). In 2008 at the International Ministerial Conference on Avian and Pandemic Influenza in Egypt, One Health became the recommended approach to infectious disease and a political reality. Participants in this conference endorsed a new strategy for fighting avian influenza and other infectious diseases, one that focused on infectious disease control in areas where animals, humans, and ecosystems meet. Finally, in 2012, the first One Health Summit was held by the Global Risk Forum in Switzerland (CDC, n.d.-c).

ZOONOTIC DISEASE

The focus of the One Health Initiative is on the connections between different areas of health and medicine. The primary way in which these domains interact is through communicable diseases. A zoonotic disease can be defined as a disease that is communicable between animals and humans. Some zoonotic diseases are widely known, such as Lyme disease and malaria, while others are less commonly understood.

Animals play important practical and emotional roles in our society. Many people interact with animals every day in a variety of environments. For any number of reasons, people are constantly coming into close contact with animals or animal byproducts. The density of modern society and the proximity in which we are required to live with animals and with each other lends itself to making the transmission of zoonotic disease inevitable. These diseases have become increasingly more common through history; it is estimated that more than six out of every ten known infectious diseases are spread from animals (CDC, n.d.-d). There are several ways in which these diseases are spread from animals to humans: direct contact, indirect contact, vector-borne, aerosol, and foodborne.

Direct contact transmission is the transmission of a zoonoses through the bodily fluids (saliva, blood, urine, mucous, feces, etc.) of an infected animal. A person becomes exposed when the pathogen makes direct contact with an open wound, mucous membranes, or the skin. Indirect contact transmission occurs by humans encountering a place an infected animal has been or lived. Indirect contact transmission involves fomites, which are inanimate objects that can carry pathogens from an animal to a person. Fomites are most commonly objects like needles, clothing, and bedding. Vector-borne transmission involves being bitten by a tick or other insects like mosquitos and fleas. Aerosol transmission of pathogens occurs when droplets from an infected animal are passed through the air and inhaled by a person. Lastly, foodborne transmission occurs when people eat contaminated or unsafe food.

Preventing zoonotic disease requires coordinated actions by governmental organizations responsible for animal and human health. For targeted actions to eliminate zoonotic disease to be effective, a framework of interdisciplinary collaboration must be constructed. While collaboration between health-centered organizations may seem intuitive or simple, many real-world situations lack cooperation between organizations necessary for effective disease prevention and control. The lack of cooperation between disciplines is typically due to lack of resources, disparities in institutional priorities and culture, and varying legal authorizations. These factors lead to difficulty in building a structured curriculum for the implementation of an interdisciplinary solution. One-sided solutions, from both animal and human health sectors, are well-intentioned, but far less effective in preventing the transmission of zoonotic diseases.

The list of communicable diseases is extensive, but several diseases provides special insight into the benefits of a One Health approach to controlling communicable diseases. These diseases hold greater weight due to their prevalence and treatability. Query fever, rabies, and recent outbreaks of zoonotic diseases can be studied in order to more fully understand approaches that have been effective in disease control and what can be done in the future to better ensure health between animals, people, and the environment.

QUERY FEVER

Query fever, known as Q fever, is an acute febrile rickettsial disease caused by *Coxiella burnetti* (Chin, 2000). This organism is unusually stable, can reach high concentrations in animal tissues (particularly placentae), and is resistant to many disinfectants. The disease is most commonly transmitted by airborne dissemination of *Coxiella* in dust from premises contaminated by tissues and fluids of infected animals. Onset of Q fever is characterized by sudden chills, headache, weakness, malaise, and severe sweats. There is considerable variation in duration and severity of this disease.

Q fever has been reported in all areas of the world. Incidences of Q fever are higher than reported due to the mildness of many cases, limited clinical suspicion, and lack of access to diagnostic laboratories. There are many reservoirs for this disease including dogs, sheep, cattle, goats, cat, birds, ticks, and some species of wild rodents. Due to this wide range of potential reservoirs, epidemics of Q fever have occurred in stockyards, meat packing and rendering plants, laboratories, and veterinary centers that use sheep in research (Chin, 2000).

The estimated infective dose via the aerosol route is slightly above one bacterium; this is indicative of a high risk of infection. If several groups of animals are affected simultaneously, human epidemics are likely to follow (Mori & Roest, 2018). In addition, animals infected with Q fever often appear healthy, making infection more likely.

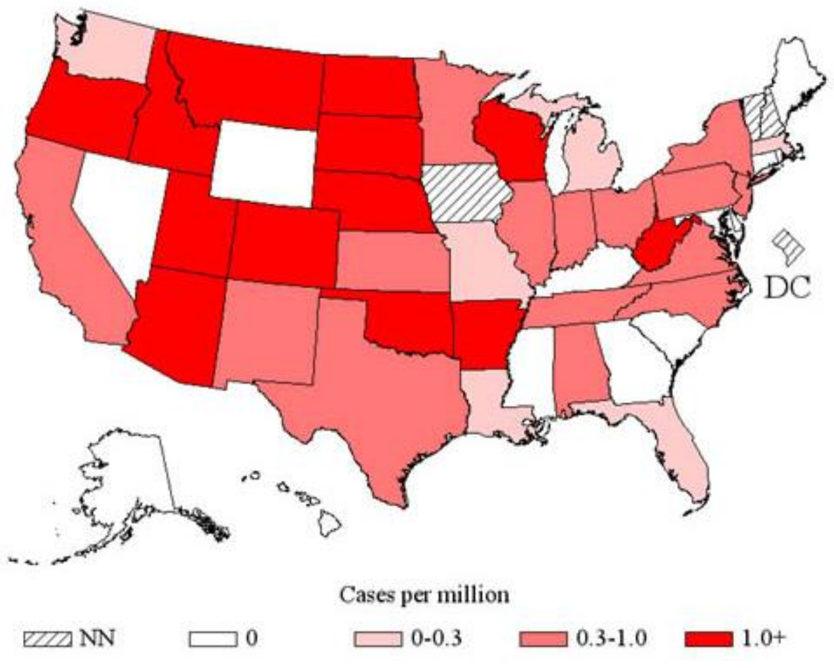

Figure 1. Geographical distribution of Q Fever incidences in the United States in 2014. The scale given represents reported cases per million people. A designation of "NN" represents a state in which Q fever was not notifiable (CDC, n.d.-b).

Incidences of Q fever vary on a state-by-state basis, being the most common in western states where rearing livestock is more common (Figure 1). Prevention is mostly achieved by avoiding raw milk and raw milk products and avoiding contact with animals. Both "passive" and "active" methods of surveillance of Q fever are employable. In passive surveillance, diagnostic testing should be done if a series of abortions occurs. In active surveillance, sampling occurs regularly based on the epidemiological needs of an area. Active surveillance, although costly, is recommended for areas where disease prevalence in animals and humans is high. Screening abortions for Q fever agents and regular bulk tank milk (BTM) monitoring can be put in place to contain Q fever. These precautionary measures have been in place in places like the Netherlands since before 2010 when a Dutch Q fever outbreak occurred (Mori & Roest, 2018).

Domestic ruminants are typically the source of Q fever in humans. By controlling Q fever outbreaks in the animal reservoir, a reduction in occurrences of Q fever in humans will follow. Options to control Q fever can be divided into four groups: identification of infected farms, reduced excretion of *C. burnetti,* reduced dispersion of *C. burnetti,* and reduced human exposure (Mori & Roest, 2018). In order to identify infected farms small, achievable steps can be taken. For example, requiring farms to notify symptoms of Q fever, abortions, or a positive BTM result to the government.

Measures taken to reduce the excretions of *C. burnetti* include vaccination with a phase 1 vaccine, breeding bans, and culling infected ruminants. Phase 1 vaccinations reduce abortions and the excretion of *C. burnetti.* Breeding bans help reduce the excretion of *C. burnetti* by preventing ruminants from becoming pregnant. Culling infected ruminants prevents already-pregnant animals from giving birth and excreting *C. burnetti.* Both culling and breeding bans were methods implemented in the Dutch Q fever outbreak (Mori & Roest, 2018). Preventing a dispersion of *C. burnetti* focuses on a larger area and entails disallowing the transport of infected goats and manure from infected herds. In addition, diligence in the sanitation of infected areas is necessary for preventing the spread of Q fever. Avoiding human exposure can be achieved through a visitor ban on Q fever positive farms. Such a ban was implemented in the Dutch outbreak.

Prior to the Dutch Q fever outbreak, cases of the disease were rare, with only a few cases occurring every year. In 2005, abortion in goats began to appear and by 2007 the first human outbreak occurred in the Netherlands. Between 2007 and 2010 about 4,000 human cases were reported (Mori & Roest, 2018). Initially in the Q fever outbreak, the restriction of information by privacy legislation hindered the ability to quickly identify the sources of human Q fever cases. In this case, it became clear that there was a disconnect between the focus of public health and animal sectors. The result of the Q fever outbreak was the formation of a national zoonosis structure with a signaling forum that meets monthly. The goal of the committee is to assess the risk of disease signals from both the human and the veterinary field at an early stage so that action can be taken to avoid outbreaks (Mori & Roest, 2018).

The transmission, host spectrum, and survival of *C. burnetti* make the biology of Q fever complex. These factors make Q fever an excellent example of a disease that requires a One Health approach and the outbreak in the Netherlands illustrates both problems that typically arise in a Q fever outbreak and how these problems can be overcome.

RABIES

Rabies is acute viral encephalomyelitis that is almost always fatal. Onset of rabies is characterized by a sense of apprehension, headache, fever, malaise, and indefinite sensory changes. The disease progresses to paresis or paralysis, spasm of swallowing muscles leads to hydrophobia, and delirium and convulsions typically follow. Without any medical intervention, the duration of this condition is typically two to six days and death is typically due to respiratory paralysis. Diagnosis of rabies is made by staining of brain tissues or by virus isolation in cell culture systems (Chin, 2000). As seen in Figure 2, histopathologic evidence of rabies encephalomyelitis in brain tissue and meninges includes mononuclear infiltration, perivascular cuffing of lymphocytes or polymorphonuclear cells, lymphocytic foci, babes nodules consisting of glial cells, and Negri bodies (CDC, n.d- a). In 1903, Dr. Adelchi Negri identified round or oval inclusions in the cytoplasm of nerve cells of infected animals- he named these Negri bodies and believed they were the etiologic agent of rabies. Negri bodies are only present in about 50% of samples from rabid animals, while a Direct Fluorescent Antibody (dFA) test shows rabies antigen in nearly all samples. Despite some shortcomings, Negri bodies provide one way to supplement diagnostics for rabies in conjunction with other testing (CDC, n.d.-a).

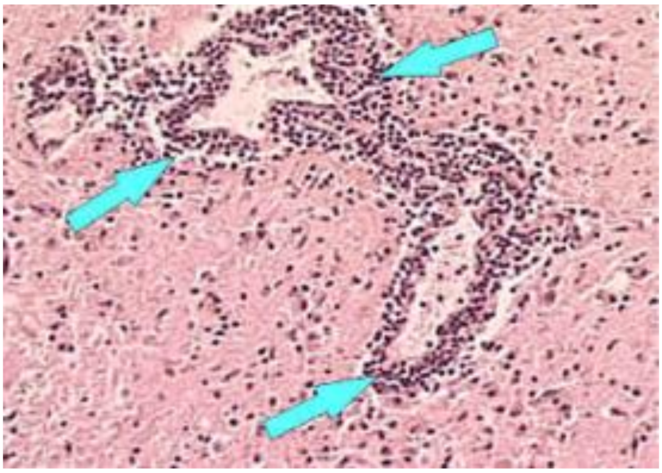

Figure 2. Inflammation around blood vessel in rabies-infected individual. Perivascular inflammatory cell infiltrates in hematoxylin and eosin brain tissue at 100x magnification (CDC, n.d.-a).

Rabies virus is a rhabdovirus of the genus *Lyssavirus*. An estimated 35,000-40,000 deaths occur from rabies worldwide each year, most of which are in developing countries. In the U.S., human rabies deaths have decreased since the 1950s as a result of routine immunization of domestic felines and canines and the increasingly effective postexposure prophylaxis regimens (Chin, 2000). Urban rabies is transmitted by dogs, while sylvatic rabies is transmitted by wild carnivores and bats, with some spillover to domesticated animals (pets and livestock). In developing countries, dogs remain the primary reservoir for the rabies virus. The mode of transmission of rabies is through the saliva of a rabid animal which is introduced by a bite or a scratch most commonly. Transmission between people is theoretically possible but has never been documented. The incubation period is typically 3-8 weeks depending on the site of the wound and its proximity to nerve supply and the brain. The period of communicability is typically 3-7 days before the onset of clinical signs and throughout the course of the disease.

There are many preventative measures that can be taken to combat the rabies virus. One thing that can be done is to register, license, and immunize canines in enzootic countries. Education of pet owners in restricting their pets and active surveillance are important steps in preventing the spread of the virus as well. Animals that have bitten a person can be detained and observed for ten days. Signs of rabies will usually appear within four to seven days, with a change in behavior and excitability or paralysis, followed by death. Oral immunization of wildlife animal reservoirs has been effective in Canada and parts of Europe. Cooperative programs with wildlife conservation authorities should be developed and individuals who are at high risk of being exposed to the virus should be administered the preexposure vaccinations (Chin, 2000).

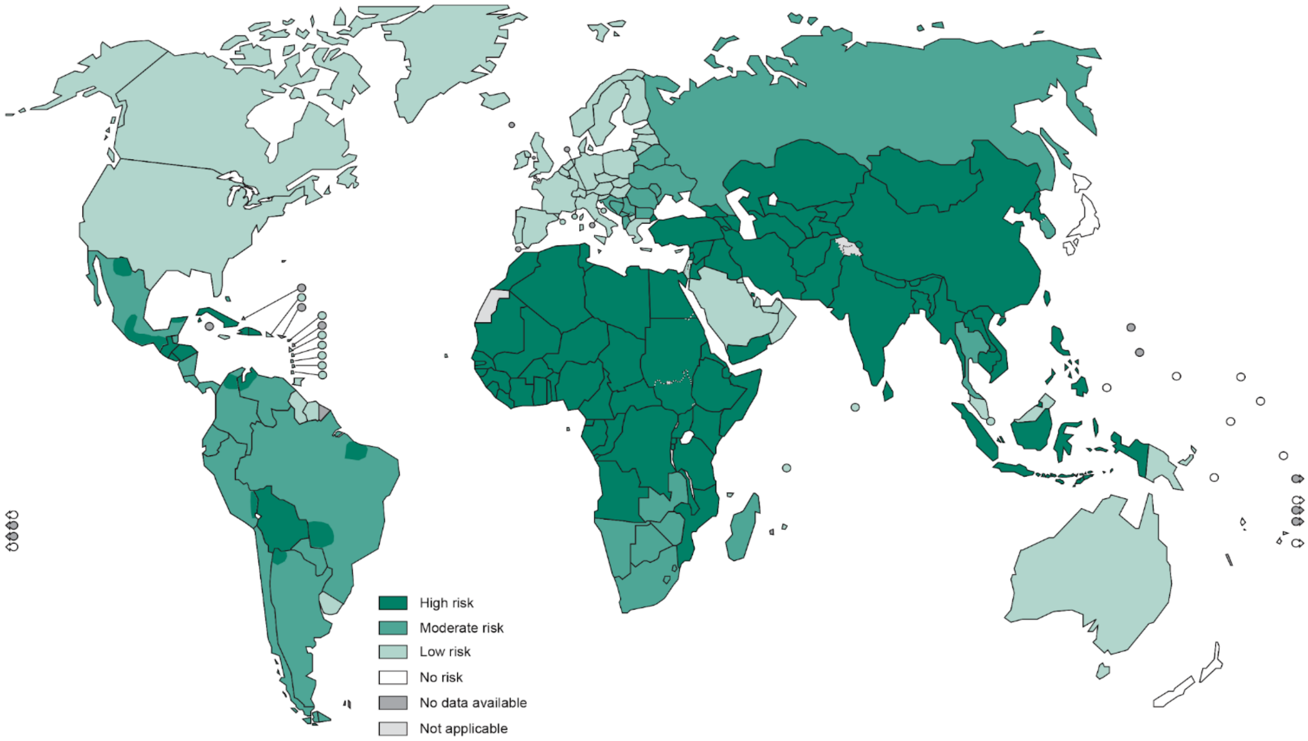

Figure 3. Distribution levels of humans contracting rabies, 2018 (WHO).

In many developing countries, canine rabies is endemic. Countries in Africa and Asia, including India and China, see the highest prevalence of rabies globally (Figure 3). Many prevention programs focus on increasing access to vaccines for postexposure prophylaxis (PEP) while investing very little in the veterinary approach to the issue (vaccinations for canines). While investments in PEP vaccines is a step towards the goal of better public health and the elimination of occurrences of rabies, PEP vaccines do not eliminate the original reservoir of rabies residing in the local population of canines. Countries in which rabies is endemic typically have large populations of stray dogs- these serve as a reservoir for rabies. In the absence of an effort to eliminate the rabies virus from the primary reservoir, there is a high cost associated with attaining, distributing, and administering PEP vaccines. Therefore, this one-sided approach to eradicating the rabies virus is not sustainable, especially for developing countries.

Successfully enacting simple measures to promote coordination of multidisciplinary action would significantly increase the likelihood of a successful disease prevention and control program, especially in settings that lack access to adequate resources. It is important for veterinary professionals to be trained to recognize symptoms of zoonotic disease in humans. An example of the use of a more comprehensive program to lessen the occurrences of rabies can be illustrated in Ethiopia in 2015.

Ethiopia used a comprehensive, or umbrella, approach to implement the Rabies Prevention and Control Program. The program is based on collaboration between the Ethiopian Public Health Institute, the Ministry of Livestock and Fisheries, Addis Ababa Urban Agriculture Bureau, and the US Center for Disease Control and Prevention (Shiferaw et al., 2017). These organizations collaborated to identify that rabies was the priority zoonotic disease in Ethiopia at the time. Rabies was identified as such because canine rabies is endemic to Ethiopia, with an estimated 105 dog bites per 100,000 people and approximately two deaths per 100,000 people occurring each year. Ethiopia's rabies-prevention program implemented laboratory-based surveillance, sustained canine mass-vaccination programs, increased access to human PEP vaccines, efforts around education, legislation, and government support.

In resource limited environments, the PEP vaccines and animal bite surveillance programs receive priority while other programs are not able to be funded. In contrast to the effective One Health or umbrella approach taken by Ethiopia, China's rabies prevention efforts provide an example of ineffective rabies control efforts. A rabies epidemic plagued China in the eighties and subsided in the late nineties. In 2012, however, rabies was detected in 77 counties, killing 663 people, indicating a need for better prevention and control measures. Rabies virus affects certain demographics more than others. Adult farmers were the most common patients (64%) followed by children living in rural areas (Zhang et al., 2018). The unequal distribution of rabies observed in different areas is indicative of both human-environment interactions and resource disparities. Although it is logical that populations that interact more closely with their environment are at a higher risk of being exposed to rabies, preventative measures are not taken to ensure these people will be more protected from the rabies virus. A One Health approach to rabies seeks to investigate the relationships between humans and their environment more closely and could prevent transmission to those in rural environments where they may be more likely to contract rabies and less likely to have access to adequate health care.

NIPAH VIRUS

Nipah virus (NiV) encephalitis is an emerging infectious disease of critical importance in the Southeast Asia region. NiV typically infects bats, pigs, and humans. Both animal-to-human and human-to-human transmission have been documented. With bats and pigs both serving as reservoirs for NiV, measures to control the virus must consider both populations and how humans interact with these animals. Between 1998, when the virus was recognized, and 2015, more than 600 cases of NiV were reported (Chattu et al., 2018). The virus first appeared in Malaysia in 1998, when 276 cases where reported with 106 fatalities (36%); this outbreak required the culling of over one million pigs to eradicate. Later outbreaks in both India and Bangladesh were associated with much higher fatality rates, between 40 and 70% (Paul, 2018). The infection has a wide range of clinical presentations. Patients may present as asymptomatic, with acute respiratory syndrome, or fatal encephalitis. Because the initial signs and systems of NiV are nonspecific, diagnosis is not suspected at the time of presentation. The resultant delay in diagnoses presents new challenges for outbreak detection and control.

The reservoir for the virus is fruit bats. Over 50 species of these bats are distributed throughout Southeast Asia. Given this distribution, outbreaks of the virus are likely to continue to occur as the populations persist and migrate (Figure 4). The infected bats shed virus in their excretion and secretion but are symptomless carriers of the virus.

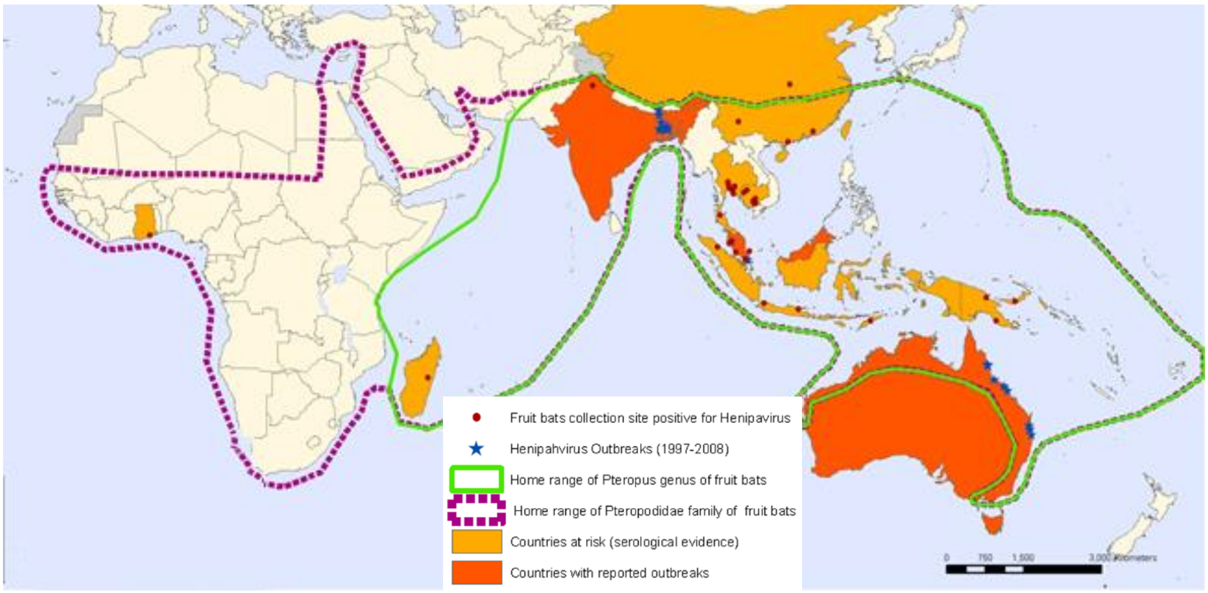

Figure 4. Geographic distribution of Nipah virus outbreaks and fruit bats of the Pteropodidae Family. (WHO, 2018).

Transmission of the virus from humans occurs through inhalation, contact, or consumption of NiV contaminated foods (Chua et al., 2002). Human-human transmission is particularly notable in outbreaks observed in India and Bangladesh, where it was reported to account for 50-75% of cases. No vaccines currently exist and treatment for the virus is solely supportive (Chattu et al., 2018). In the absence of an effective vaccine, the best way to prevent exposure is to educate people on the virus and measures that can be taken to reduce infection.

Strategies to survey and prevent NiV outbreaks include reducing risk of infection in domestic animals, people, and in healthcare settings. Routinely cleaning pig farms and immediately quarantining any animals suspected of infection may be effective in preventing infection, in addition to culling of infected animals. NiV outbreaks in animals have preceded human outbreaks. Establishing an animal surveillance system, using a One Health approach, to detect cases of NiV in animals is essential in providing early warning for healthcare providers.

Interactions between humans, animals, and the environment are especially important in NiV outbreaks. Deforestation and urbanization in Southeast Asia have created greater overlap between human and bat habitats. The newfound sharing of space between local populations of humans and animals has created a greater risk for “spillover events.” These “spillover events” are when NiV crosses the species barrier and infects people (Chattu et al., 2018). In addition, domesticated animals that consume infected fruit can also become infected. The most prevalent way that humans become infected, however, is through the consumption of raw date palm sap, a delicacy in many parts of Southeast Asia. This sap is collected from trees where it can be contaminated by virus-containing bats. Once infected, people can transmit NiV to each other, causing local epidemics (Chattu et al., 2018).

The latest outbreak of NiV occurred in Kerala state, India. The first case detected when three family members died in the process of cleaning an old well infected by the bats. The outbreak began in May, 2018; as of June 1, 2018 there were 17 deaths and 18 confirmed cases (WHO, 2018). A multidisciplinary team from the National Center for Disease Control was formed consisting of epidemiologists, pulmonologists, emergency medicine specialists, and experts in zoonosis and animal husbandry (Chattu et al., 2018).

This team took precautions to advise hospitals and survey the community. The community surveillance consisted of fever surveillance in humans and unusual illness and deaths in animals. This team also began screening bat population for the virus as well as attempting to clean water sources. The multidisciplinary team created helped to keep the virus contained by early detection and use of an “umbrella” approach, covering human and animal health communities. Although it cannot be confirmed that the outbreak would have had more lethal impacts without the formation of this team, this outbreak resulted in fewer deaths than in previous outbreaks as a result of effective management by a multidisciplinary team.

FACTORS CONTRIBUTING TO EMERGING AND REMERGING ZOONOSES

Infectious diseases, including zoonotic diseases, have a complex relationship with culture and geography. The geographical distribution of infectious disease has changed over time with the emergence of human settlements and increase in population density. The convergence of people, animals, and our environment has created a new healthcare dynamic. Social and environmental conditions are external factors and include mobility, population growth, urbanization, and environmental changes like agriculture, climate change, and deforestation.

An example of an area where population plays a large role in emerging infectious disease is China, where approximately 20% of the total world population lives on 6.7% of world land (Liu et al. , 2014). As population grows, the increased susceptible population grows as well, thereby increasing the potential for disease transmission. Avian influenza serves as an example of China's susceptibility to emerging infectious disease. The first identified cases of avian influenza appeared in China in February and March of 2013 and impacted 12 areas of China and resulted in 47 deaths (Li et al., 2014).

Urbanization has significant public health implications as well. Urban environments increase zoonotic transmission by water or air in addition to increasing the transmission of insect- and animal-borne disease due to poor healthcare systems and inadequate infrastructure. In urban environments, garbage provides a food and habitats for rodents and other stray animals that may serve as reservoirs for disease. Inadequate water supply in many growing urban areas leads people to store water, creating a habitat for the larvae of insects like mosquitoes.

Environmental degradation promotes expansion of infectious diseases and non-infectious threats. Human exploitation in the form of logging, mining, road construction, and agricultural production have resulted in deforestation. Deforestation is the beginning of a cascade of events that accelerate the emergence of zoonoses. The destruction of habitats forces an increase in human-animal interactions and leads to increased transmission of pathogens either directly or indirectly. Climate change also influences disease transmission as increased temperatures can enhance pathogen development, disease transmission, and host susceptibility (Liu et al., 2014).

Resource disparities also play a significant role in the successful implementation of any disease prevention program. Using a One Health approach requires the simultaneous launch of many multidisciplinary prevention efforts which can be challenging in a resource-limited environment. Existing surveillance systems have been developed and implemented with a bias towards developed countries. Here the healthcare and food safety systems find themselves incubating infections in the areas of the world most at risk.

FOOD SAFETY

Approximately 48 million cases of food-borne illness occur annually in the United States (Choffnes et al., 2012). Of these cases, approximately 130,000 result in hospitalization and 3,000 result in death (Lammie & Hughes, 2016). These incredibly high incidences indicate that a One Health approach is needed in our rapidly changing global food system. With the rise of food animal production and the resultant transportation of agricultural products globally, many countries are struggling to match production with food safety technology. Globalization of our food supply has not only expanded the range of a single pathogen, but also amplifies the impact of a single contamination incident (Figure 5).

Figure 5. "The Well-Traveled Salad" indicates different areas of the world from which certain products come (Choffnes et al., 2012).

Late in the summer of 2011, one of the deadliest outbreaks of listeriosis in the United States occurred, marking one of the first times this pathogen was found in fresh produce. 139 illnesses, 29 deaths, and one miscarriage were attributed to infections during this outbreak. The outbreak was eventually traced back to a cantaloupe producer in Colorado that had distributed melons to supermarkets and chain stores in at least 28 states (Choffnes et al., 2012). This is only one of numerous examples of food-borne illness that spread rapidly due to modern farming and agricultural systems. More than 250 pathogens and toxins are known to be transmitted by food including *Campylobacter, Clostridium perfringens, E. coli, Listeria monocytogenes,* Norovirus, *Salmonella* spp., and *Toxoplasma* (these alone account for 90% of food-related illnesses) (Choffnes et al., 2012).

In the effort to produce food more efficiently, transportation of large livestock herds, flocks of birds, or schools of fish/shellfish create conditions for disease emergence and spread. The invention of refrigeration, instantaneous communication, and rapid transportation support food distribution globally. These systems, in turn, link the United States with more than 200 countries and territories in terms of food safety and food conditions (Choffnes et al., 2012). Food distribution networks are designed to rapidly move perishable goods, to provide restocking just short of expiration, and to take advantage of economies of scale (Choffnes et al., 2012). Herein lies the disconnect between health and business.

Meat consumption has been rising steadily since 1983 in developed countries and is rising rapidly in developing countries. In 2010, nearly 10 billion food animals were produced. If this demand continues to rise at its projected rate, another 15 billion animals will be needed to feed the world's population over two decades (Choffnes et al., 2012). This is relevant to One Health because the rising meat industry and demand for animal byproducts increases interaction between humans and animals more than ever before in history. In addition, this heightened demand for meat products has led us to resort to getting meat from farther away. For example, the meat consumed at a typical American table has traveled on average 1,000 miles from its farm (or farms) of origin (Choffnes et al., 2012). This long distance transportation of food products provides an opportunity for the introduction of new microbes into new geographical areas. This migration of microflora has important implications in food safety.

Three environmental factors can be focused on as being particularly relevant in the spread of food-borne pathogens. These include intensive agricultural practices, increased interactions between humans, domestic animals, and wildlife, and environmental communal resources. Intensive agricultural practices are driven by a desire for efficient production, but often do not align with the most health-conscious practices. Environmental "commons" include water or other communal resources, that can facilitate the spread of disease.

Regarding food science, we have reached an era where old models are beginning to fail as our system of agriculture moves beyond what would have been imaginable before. A new model has yet to be created but must emphasize the importance of a One Health approach. For example, moving from reactive programs to proactive, preventative, and anticipatory programs is necessary (Choffnes et al., 2012). The complexity and scale that modern diets have taken on require scientists, researchers, and other health professionals move beyond the scope of their traditional job title to embrace the interdisciplinary nature of modern food science. One issue the One Health concept faces in food safety is the demand-driven economy. In this economy, large manufacturers and stores attempt to meet the demands of consumers by selling food at the lowest price possible; in this system, coalitions of companies set the standards for food safety ahead of governments and international organizations.

Another issue is the "culture clash" experiences when different cultures assign responsibility for food safety differently (Choffnes et al., 2012). Disconnects exist between countries where food is produced and where food is consumed due to differences in development. The typical disconnect is that countries that are responsible for much of the food delivered to highly developed countries are economically underdeveloped. In developing countries, food safety is often not prioritized over the value of exporting goods to generate foreign currency reserves (Choffnes et al., 2012).

ONE HEALTH AND ANTIMICROBIAL RESISTANCE

Antimicrobial resistance is arguably the largest problem currently facing medicine. To find a solution to this problem will require interdisciplinary cooperation beyond what we have seen in the past. Given the intricacies of antimicrobial resistance, it seems increasingly important to consider a One Health approach to this problem, where human, animal, and environmental health are at an interface.

Four primary action areas have been identified: stewardship, infection control, resistance tracking, and novel antibiotic and diagnostic testing (Lammie & Hughes, 2016). Inappropriate antibiotic use is a prevalent issue in human medicine. Misuse of antibiotics, over-the-counter availability, poor patient adherence to prescribed medications, use of substandard medications, and self-mediation with previously unused antibiotics are all factors that contribute to the global issue of antimicrobial resistance (Lammie & Hughes, 2016).

The agriculture use of antibiotics is an important point at which human and animal health intersect. Subtherapeutic levels of antibiotics intended for growth promotion in combination with overcrowded farming conditions are thought to contribute to antibiotic resistance. The use of antibiotics in agriculture in addition to their use in medicine creates selective pressures on microbial populations from multiple reservoirs. In the former East Germany, nourseothricin, an antimicrobial drug, was used as a growth promoter from 1983 to 1990. Prior to 1983, resistance to the drug was negligible. However, in just two years resistance was found in the gut of pigs and in meat products. By 1990, resistance to nourseothricin had spread to pig farmers, their families, and citizens of nearby communities (as determined by patients suffering from resistant urinary tract infections) (Wolfgang, 1998). This serves as one example of how agricultural use of antibiotics can affect the surrounding community.

Studies show that drug-resistant *Salmonella* discovered in food animals and humans transferred resistance to other enteric bacteria, which broadens the scope of the issue (Choffnes et al., 2012). Not only has it been discovered that *Salmonella* is drug-resistant, but there are also drug resistant strains of *Campylobacter jejuni, Clostridium difficile,* and *Staphylococcus aureus* (Lammie & Hughes, 2016). The result of this discovery was the recommendation that only antibiotics with limited use in human medicine be used in agriculture and growth promoters.

Due to the growing knowledge that resistance can be transferred by way of the food supply, it is imperative that human medicine and agriculture collaborate. This collaboration could consist of determining which antimicrobial drugs are appropriate for use in human medicine, veterinary medicine, and in agriculture. Drawing specific distinctions about dosage allowed and type of antimicrobial allowed can help slow the process of resistance evolution. In addition, using a One Health approach could lead to greater transparency between sectors of health and agriculture. Not only would greater transparency occur but trust, communication, and collaboration result from a One Health approach to antibiotic resistance. A problem as multifaceted as antibiotic resistance merits a solution that is as dynamic as the problem itself.

ONE HEALTH SOLUTIONS

The first step in successfully implementing a One Health disease control approach is to generate a zoonotic priority list. This small but significant step allows human health and animal health practitioners to understand that different diseases hold differing levels of significance between two realms of medicine. Collaborating to create a comprehensive list of zoonotic priorities allows for consensus to be reached and increases commitment, motivation, and focus to the implementation of a formulated plan (Shiferaw et al., 2017).

Formulation of specific laws and regulations allows the government at all levels to report, control, and treat infectious disease emergencies effectively. Without these procedures set in place, many outbreaks remain unchecked as the governments struggle to invent a framework for controlling disease. A major part of the success of the control of communicable diseases is the creation of an effective disease reporting system. Ensuring that a report system is in place allows public health officials to act quickly to enforce the control strategies outlined.

Lastly, health education is an important factor in disease prevention. Ensuring that people know healthy ways to prepare animal products and care for pets will help reduce transmission. All of these solutions can be used by different sectors of health in order to prevent disease transmission- the most important step now is to spread the concept of the One Health initiative globally.

REFERENCES

AVMA. (n.d.). One Health - What is One Health? Retrieved December 20, 2018, from https://www.avma.org/KB/Resources/Reference/Pages/One-Health94.aspx

CDC. (n.d.-a). CDC - Diagnosis: Histologic Examination - Rabies. Retrieved December 20, 2018, from https://www.cdc.gov/rabies/diagnosis/histologic.html

CDC. (n.d.-b). Epidemiology and Statistics | Q Fever | CDC. Retrieved January 22, 2019, from https://www.cdc.gov/qfever/stats/index.html

CDC. (n.d.-c). History | One Health | CDC. Retrieved December 20, 2018, from https://www.cdc.gov/onehealth/basics/history/index.html

CDC. (n.d.-d). Zoonotic Diseases | One Health | CDC. Retrieved October 31, 2018, from https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html

Chattu, V. K., Kumar, R., Kumary, S., Kajal, F., & David, J. K. (2018). Nipah virus epidemic in southern India and emphasizing “One Health” approach to ensure global health security. *Journal of Family Medicine and Primary Care*, *7*(2), 275–283. https://doi.org/10.4103/jfmpc.jfmpc_137_18

Chin, J. (2000). *Control of Communicable Diseases Manual* (17th ed.). American Public Health Association.

Choffnes, E. R., Relman, D. A., Olsen, L., Hutton, R., & Mack, A. (2012). Improving Food Safety Through a One Health Approach. Washington, D.C.: Institute of Medicine. Retrieved from http://www.nap.edu.

Chua, K. B., Koh, C. L., Hooi, P. S., Wee, K. F., Khong, J. H., Chua, B. H., … Lam, S. K. (2002). Isolation of Nipah virus from Malaysian Island flying-foxes. *Microbes and Infection*, *4*, 145–151. Retrieved from www.elsevier.com/locate/micinf

Lammie, S. L., & Hughes, J. M. (2016). Antimicrobial Resistance, Food Safety, and One Health: The Need for Convergence. *Annual Review of Food Science and Technology*, *7*, 287–312. https://doi.org/10.1146/annurev-food-041715-033251

Li, Q., Zhou, L., Zhou, M., Chen, Z., Li, F., Wu, H., … Li, F. (2014). Epidemiology of Human Infections with Avian Influenza A(H7N9) Virus in China A bs tr ac t. *New England Journal of Medicine*, *6*(6), 520–552. https://doi.org/10.1056/NEJMoa1304617

Liu, Q., Cao, L., & Zhu, X.-Q. (2014). Major emerging and re-emerging zoonoses in China: a matter of global health and socioeconomic development for 1.3 billion. *International Journal of Infectious Diseases*, *25*, 65–72. https://doi.org/10.1016/j.ijid.2014.04.003

Mori, M., & Roest, H.-J. (2018). Farming, Q fever and public health: agricultural practices and beyond. *Archives of Public Health*, *76*(2). https://doi.org/10.1186/s13690-017-0248-y

Paul, L. (2018). Nipah virus in Kerala: a Deadly Zoonosis. *Clinical Microbiology and Infection*, *24*(April 2004), 1113–1114. https://doi.org/10.1016/j.cmi.2018.06.017

Shiferaw, M. L., Doty, J. B., Maghlakelidze, G., Morgan, J., Khmaladze, E., Parkadze, O., … Reynolds, M. G. (2017). Frameworks for Preventing, Detecting, and Controlling Zoonotic Diseases. *Emerging Infectious Diseases*, *23*, 71–76. https://doi.org/10.3201/eid2313.170601

WHO. (2018). World Health Organization, Nipah Virus. Retrieved February 1, 2019, from http://www.searo.who.int/entity/emerging_diseases/links/nipah_virus/en/

Wolfgang, W. (1998). Inactivation of antibiotics and the dissemination of resistance genes. *Science*, *279*(5353), 375–382. https://doi.org/10.1126/science.279.5353.996

Zhang, H.-L., Zhang, Y.-Z., Yang, W.-H., Tao, X.-Y., Li, H., Ding, J.-C., … Tang, Q. (2014). Molecular Epidemiology of Reemergent Rabies in Yunnan Province, Southwestern China. *Emerging Infectious Diseases*, *20*(9). https://doi.org/10.3201/eid2009.130440