The One Health Approach to Emerging Infectious Diseases: Ebola and the Animal Health Perspective

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ABSTRACT

The fundamental basis for the One Health concept is rooted in the interconnectedness of animal, human, and environmental health. Because of these complex linkages, supporters of One Health advocate that effective solutions to public health challenges require multi-disciplinary communication, collaboration, and coordination.

The One Health concept dates back to the mid-19th century to Rudolph Virchow who understood the value of incorporating medicine and veterinary medicine into public health. He and other prominent scientists of the 19th and early 20th century championed the One Health approach, leading to scientific and medical breakthroughs that still benefit us today. After a quiescent period, the One Health concept underwent a rebirth as increasingly more frequent infectious disease outbreak events [i.e., severe acute respiratory syndrome (SARS), avian influenza, bovine spongiform encephalopathy (BSE), and West Nile virus] captured global attention and revealed vulnerabilities in preparedness and response methods to combat zoonotic and emerging infectious diseases. In the early 21st century, the One Health approach gained a foothold in the public health realm as a viable and feasible system to address challenges at the human-animal-environment interface.

In 2014, when Ebola virus disease struck the United States (US), the public looked towards government agencies and health organizations to respond swiftly and appropriately. From the animal health perspective, United States Department of Agriculture (USDA) responded by activating a departmental-level One Health task force to coordinate multi-agency response activities across various public health disciplines. The One Health approach is reviewed and evaluated for the feasibility of incorporating human, animal, and environmental health at the

federal level; the degree of integration across multiple disciplines; and the ability of the response to improve and benefit overall health outcomes. The approach proved to be an effective mechanism for dealing with animal health-related components and provided valuable lessons learned for improving response mechanisms for future One Health events. With continued implementation and integration, the One Health approach is an attainable and beneficial method to combating zoonotic and emerging infectious diseases and other public health issues at the human-animal-environment interface.

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CHAPTER I

INTRODUCTION

One Health Defined

The One Health concept has many varied definitions all centered around the common idea that human, animal, and environmental health are intricately linked and multidisciplinary, collaborative efforts are necessary to find effective public health interventions and preventive strategies (Atlas, 2013; Gibbs & Gibbs, 2013; Monath, Kahn, & Kaplan, 2010). The American Veterinary Medical Association (AVMA) defines One Health as “the collaborative efforts of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and our environment” (AVMA, 2015, para. 1). The European Union defines One Health as:

> The improvement of health and well-being through (i) the prevention of risks and the mitigation of effects of crises that originate at the interface between humans, animals and their various environments, and (ii) promoting a cross-sectoral, collaborative, ‘whole of society’ approach to health hazards, as a systemic change of perspective in the management of risks. (Gibbs & Gibbs, 2013, p. 33)

Similarly, the Food and Agriculture Organization of the United Nations (FAO) adopts a broad, rather flexible definition while other international agencies such as the World Health Organization (WHO) and the World Organization for Animal Health (OIE) adhere to a more restricted definition that focuses primarily on zoonotic threats (Gibbs & Gibbs, 2013).

The One Health approach seeks to bring together professionals from various disciplines including veterinarians, physicians, agricultural scientists, anthropologists, economists, educators, engineers, entomologists, epidemiologists, hydrologists, microbiologists, nutritionists, environmentalists, public health professionals, sociologists, and wildlife specialists (Gibbs & Gibbs, 2013; Mazet et al., 2009). Traditionally, these disciplines have worked in isolation within specialized “silos” focused on individual components of disease outbreak events. The One Health approach seeks to remove disciplinary boundaries and form cross-sectoral alliances to draw upon a wider pool of knowledge networks and resources systems. The One Health approach is built upon the premise that a holistic approach to health policies and interventions yields a larger health benefit than individually addressing disease components in isolation (Mazet et al., 2009).

Purpose of Paper

The purpose of this paper is to provide an overview of the evolution of the One Health concept as a viable systems thinking strategy to respond to zoonotic and emerging infectious diseases that occur at the human-animal-environment interface. Within USDA, the One Health approach was used to respond to the 2014 Ebola outbreak in the United States. The Ebola outbreak is used as a supportive example for applying the One Health approach to public health challenges.

CHAPTER II

LITERATURE REVIEW

The Historical Evolution of One Health

The One Health concept is not a new idea but rather one that has evolved over the past 150 years and only recently, in the past decade or so, has experienced a renaissance among scientists and health professionals in response to several emerging disease events (i.e., West Nile Virus, H5N1 avian influenza, SARS, and others) that have threatened human and animal health (Cardiff, Ward, & Barthold, 2008; Dhama et al., 2013; Gibbs, 2014). Rudolph Virchow (1821-1902), a German pathologist and considered to be the father of comparative medicine, cellular biology, and veterinary pathology, launched the One Health concept in the 19th century (Monath et al., 2010; Saunders, 2000). He is quoted as saying, "between animal and human medicine there are no dividing lines- nor should there be. The object is different but the experience obtained constitutes the basis of all medicine" (Osburn, Scott, & Gibbs, 2009, p. 481). In an era the pre-dates the universal acceptance of germ theory, he coined the term "zoonosis" to describe the infectious disease links between animal and human health (Cardiff et al., 2008; Monath et al., 2010). Virchow determined the life cycle of the nematode *Trichinella spiralis*, a parasitic roundworm that can infect humans through the ingestion of improperly cooked meat, particularly pork. He discovered that the circular structures often seen in porcine muscle tissue were not normal variations in the meat but rather the larvae of *T. spiralis* (Saunders, 2000). He used this information to develop practical applications for low power microscopic and macroscopic examination of pork meat for the detection of parasites in abattoirs and, through his involvement in parliamentary politics, he was instrumental in bringing veterinarians into sanitary abattoirs to inspect meat for human consumption as a public health protective measure. These practices were eventually adopted worldwide and solidified the public health role of veterinarians in food safety[1].

Sir William Osler (1849-1919), a Canadian physician and a student of Virchow's, was the first to coin the term "One Medicine" (this term would later evolve into "One Health") in the English language literature and to bring the idea of integrated medicine to North America (Cardiff et al., 2008; Osburn et al., 2009; Zinsstag, Schelling, Waltner-Toews, & Tanner, 2011). He is considered to be a founding father of modern medicine and the father of veterinary pathology in North America. He was influenced by Virchow's teachings on the importance of including veterinarians and farmers in public health and, like Virchow, many of the activities that he pursued professionally sought to connect medicine and veterinary medicine with each other (Monath et al., 2010; Saunders, 2000).

Several other 19th century scientists, physicians and veterinarians were important early pioneers of the One Health concept with significant scientific contributions to both human and animal health. Louis Pasteur (1822-1895) did extensive research into vaccines, including pre-exposure rabies vaccination of canines and post-exposure vaccination in humans. Robert Koch (1843-1910) studied the etiology of tuberculosis in both cattle and humans, finding a causal relationship between infection by a specific bacterium and clinical disease (Atlas, 2013). Daniel E. Salmon (1850-1914), for whom the *Salmonella* genus of bacteria was named, established the veterinary division within the USDA called the Bureau of Animal Industry (BAI). While at BAI, Salmon hired and worked with several prominent physicians including Theobald Smith (1859-

[1] In the US, federal meat inspection began in 1890 within the meat inspection division of the Bureau of Animal Industry but only for pork carcasses exported to Germany. It wasn't until the early part of the 20th century that meat inspection and sanitary abattoirs became the norm for domestic meat production through legislative action and oversight by federally-employed veterinarians and meat inspectors.

1934) who, together with Salmon, discovered that heat-destroyed pathogens could immunize humans and animals against live pathogens. This monumental discovery led to the development of the typhus vaccine and Jonas Salk's polio vaccine (Kahn, Kaplan, & Monath, 2009; Monath et al., 2010). Smith and veterinarian Frederick L. Kilborne (1858-1936) discovered that Babesiosis in cattle was a vector-borne disease transmitted by ticks; their work was thought to be the foundational work for Walter Reed's discovery that yellow fever was a vector-borne disease transmitted by mosquitoes. John McFadyean (1853-1941), both a veterinary and medical doctor and considered by many as the founder of veterinary research, linked bovine tuberculosis in milk and milk products to human tuberculosis cases, paving the way for widespread acceptance of pasteurization of milk as a key public health measure in the prevention of milk-borne pathogens (Holsinger, Rajkowski, & Stabel, 1997; Kahn et al., 2009; Monath et al., 2010).

During most of the 20th century, the collaborative spirit between veterinarians and physicians waned as veterinary medicine shifted from its origins in food animals and horses to companion animals and both professions segregated into specialized medicine and intellectual silos (Atlas, 2013; Gibbs & Gibbs, 2013; Zinsstag et al., 2011). However, the One Health concept and the term "One Medicine" resurfaced with veterinary epidemiologist and parasitologist Calvin Schwabe (1927-2006) and his 1984 book *Veterinary Medicine and Human Health* (Monath et al., 2010; Osburn et al., 2009). Known as the founder of veterinary epidemiology, Schwabe was a renowned expert on zoonotic diseases. Through his work with Dinka pastoralists in Sudan, Schwabe emphasized the interdependence of animals and animal products to human health and public well-being (Osburn et al., 2009; Zinsstag et al., 2011). The One Health concept was further championed by veterinarian James H. Steele (1913-2013). Known as the father of veterinary public health and the founder of the veterinary public health division at the Centers for Disease Control and Prevention (CDC), Steele tirelessly promoted the One Health concept throughout his more than 70 year career (referred by Steele as "One World, One Medicine, One Health"). It was Steele and his followers that paved the way for taking the vision and ideas of the One Health concept and implementing them into public health and disease control programs that were operationalized within international organizations, academia, and various levels of the government framework (Monath et al., 2010).

The Resurgence of One Health in the 21st Century

Early in the 21st century, several global disease events [i.e., West Nile Virus, H5N1 avian influenza, SARS, Ebola Hemorrhagic Fever, monkeypox, BSE, and Human Immunodeficiency Virus (HIV) decades previously] highlighted the need for cross-sectoral collaboration and generated a heightened interest among scientists and health professionals to gain a deeper understanding of the complex, interconnectedness of emerging zoonotic diseases and human, animal, and environmental health (Cardiff et al., 2008; Gibbs, 2014). In 2004, the Wildlife Conservation Society organized a conference on One World-One Health and formally extended the One Health concept to include environmental health (including wildlife and their ecosystems) (Gibbs & Gibbs, 2013). Collaborators at the conference formulated 12 recommendations called the Manhattan Principles (link) for establishing a more holistic approach to addressing emerging pandemic and epizootic diseases that threaten human, animal, and environmental health (Gibbs & Gibbs, 2013; One Health One World, 2009). In 2007, both the American Medical Association (AMA) and the AVMA passed resolutions to promote multidisciplinary collaborations between human and animal health (Cardiff et al., 2008; Dhama et al., 2013; Osburn et al., 2009). Following these commitments, the One Health Commission and the One Health Initiative were independently launched as means to conceptualize One Health ideas and principles into actionable strategic frameworks for collaboration and communication among health science professions, governmental agencies, and health organizations (Atlas, 2013; Gibbs, 2014; One Health Commission, 2015; One Health Initiative, 2015; Osburn et al., 2009). Other international agencies including FAO, WHO, and OIE developed their own guiding principles for responding to disease risks at the human-animal-environment interface. In 2009, the CDC established the One Health Office in close partnership with the USDA with a mission to “facilitate, sponsor and coordinate research and program activities that seek to attain optimal health for people and animals through an integrated approach considering the interrelatedness among humans, animals, and the environment in which they live” (CDC, 2013, para 1). In 2011, the first international One Health Congress and the first One Health Conference were held (Atlas, 2013; Gibbs, 2014).

Over the past decade, the nomenclature shifted from “One Medicine” to “One Health” to embrace a broader umbrella of concepts, including non-infectious disease applications such as the human-animal bond, comparative medicine research for cancer treatment in canines and humans, and toxic or hazardous exposure in humans and animals (Gibbs, 2014; One Health Initiative, 2015; Zinsstag et al., 2011; Zinsstag, Schelling, Wyss, & Mahamat, 2005). Today, the rapid expansion of the One Health concept has led to global acceptance of the One Health approach as a viable approach for health science professionals, government agencies, academia, and organizations.

The Rising Need for the One Health Approach

Globally, several socio-economic, demographic, and environmental factors have significantly changed, causing an upsurge in emerging infectious diseases. Rapid population growth has forced human populations to encroach upon wildlife habitats, increasing the direct contact people have with wild animals and the diseases they carry (Osburn et al., 2009).

Population growth has also increased worldwide demand for animal protein, pushing the need for increased efficiency of livestock and farm fishing. Anthropogenic environmental changes such as deforestation or agricultural intensification force wildlife reservoirs for zoonotic diseases into closer proximity to humans (Kahn, Kaplan, & Steele, 2007). Globalization of the food supply, international trade of animals and agricultural products, and the global movement of people all contribute to the rapid spread and dissemination of disease pathogens to previously unaffected regions and populations (Dhama et al., 2013; Gibbs & Gibbs, 2013). Climate change has contributed to vector-borne diseases appearing in geographic ranges previously believed to be unfit for disease maintenance (Dhama et al., 2013; Osburn et al., 2009). Other reasons such as ecotourism, water scarcity, civil unrest, political instability, and the breakdown of public health systems in developing countries have all impacted human interactions at the human-animal-environment interface (Dhama et al., 2013).

Because of these changes, there has been a significant increase in the prevalence of emerging infectious diseases in the past three decades. Approximately 60% of emerging infectious diseases in humans are caused by transmission of an infectious agent from animals; 75% of these diseases originate in wildlife. In particular, the rise in viral diseases has focused the One Health approach on animal reservoirs, particularly wildlife, as the source for epidemic disease in humans. Viral mutation or reassortment allows host preferences to expand beyond the primary specie(s), causing spillover events, particularly at porous regions between people and wildlife (Daszak et al., 2013; Day, 2011; Gibbs & Gibbs, 2013). Zoonotic disease outbreak events such as BSE, SARS, H5N1 and H1N1 influenzas, Middle East Respiratory Syndrome (MERS) and most recently, Ebola, have captured global attention and uncovered vulnerabilities in the preparedness and response of the global community to combat emerging infectious diseases. Additionally, it has placed public health systems under close scrutiny for the effectiveness of their surveillance, assessment, and treatment programs (Azhar et al., 2014; Dhama et al., 2013).

CHAPTER III

ONE HEALTH AND EBOLA VIRUS DISEASE (EVD)

There is mounting evidence for the necessity and value of multidisciplinary approaches to public health events that span across humans and animals. The One Health approach has been recognized as an important element of disease control and prevention by international agencies and organizations (Rabinowitz et al., 2013). While proof-of-concept evidence and large, controlled studies to evaluate the comparative effectiveness of the One Health approach are somewhat lacking in the literature, several successful case studies have shown that a One Health approach results in an increased health benefit for both humans and animals (Daszak et al., 2013; Mazet et al., 2009; Middleton et al., 2014; Rabinowitz et al., 2013; Rubin, Dunham, & Sleeman, 2014). The recent 2014 Ebola outbreak in the US, an extension from the on-going outbreak in West Africa, is an example of the One Health concept in action. The One Health approach is quite fitting for the EVD outbreak as the origins of the first outbreak in 1976 are rooted in a multi-disciplinary investigation. Virologists Frederick A. Murphy, a veterinarian, and Karl M. Johnson, a physician, worked closely together, along with others, to uncover the root cause of the initial outbreak of EVD (Johnson, Lange, Webb, & Murphy, 1977).

To further examine the effectiveness of the One Health approach, a review of the One Health response to EVD from the animal health perspective at the federal agency level is presented. The response will be evaluated on the feasibility of incorporating human, animal, and environmental health at the federal agency level; the degree of integration across multiple disciplines; and the ability of the response to improve and benefit overall health outcomes (Rabinowitz et al., 2013). Successes and gaps are identified and recommendations for strengthening the One Health approach are provided. It should be noted that this evaluation is only considering the USDA component of the US government EVD response. A complete evaluation of the US government response is outside the scope of this paper.

EVD in Humans

Ebola virus disease (EVD), previously known as Ebola Hemorrhagic Fever is a serious, often deadly disease caused by viruses in the family *Filoviridae*, genus *Ebolavirus*. *Ebolaviruses* are enveloped RNA viruses related to Marburg virus. There are five strains within the genus Ebolavirus: *Zaire ebolavirus*, *Sudan ebolavirus*, *Tai forest ebolavirus (*formerly *Ivory Coast ebolavirus)*, *Bundibugyo ebolavirus*, and *Reston ebolavirus*. With the exception of Reston ebolavirus, all can cause disease in humans. *Zaire ebolavirus* (referred to as Ebola) has caused several large epidemics in Africa and it is the etiologic agent responsible for the current outbreak in West Africa (Ascenzi et al., 2008; CDC, 2014a, 2014b; WHO, 2014a).

EVD was first discovered in 1976 near the Ebola River in the Democratic Republic of Congo. Between 1976 and 2013, there were approximately 20 outbreaks of EVD in East and Central Africa; most of these outbreaks were attributed to *Zaire ebolavirus*. These outbreaks were characterized by small clusters of cases, typically 500 or less, in secluded, rural locations (Brown, Arkell, & Rokadiya, 2015; Groseth, Feldmann, & Strong, 2007). In 2014, an Ebola outbreak emerged in several countries in West Africa. Phylogenetic comparisons of genomes from current and previous outbreaks suggest that the virus diverged from Central African lineages into West Africa around 2004 (Gire et al., 2014). The West African outbreak is believed to have begun in December 2013 from Guéckédou, a remote forested area in Guinea. In the early months of 2014, it quickly spread to the neighboring countries of Liberia and Sierra Leone (Brown et al., 2015). The WHO was officially notified in March 2014 and by August 2014, the

WHO had declared the epidemic to be a “public health emergency of international concern” (WHO, 2014a, p. 1481). As of March 22, 2015, there have been 24,907 cases and 10,326 deaths from EVD. Guinea, Liberia, and Sierra Leone continue to be the most-affected countries by the outbreak. Six countries—Mali, Nigeria, Senegal, Spain, the United Kingdom, and the US—have reported a case or cases imported from a disease-stricken country (WHO, 2015) and numerous cases, primarily health care workers, have been treated across Western Europe. The on-going Ebola outbreak in West Africa is by far the largest recorded EVD outbreak to date (Brown et al., 2015).

In humans, EVD has an incubation period of 2-21 days (average 8-10 days). Symptoms include fever, muscle aches, fatigue, vomiting, diarrhea, stomach pain, maculopapular rash, and unexplained bleeding (Ascenzi et al., 2008; CDC, 2014b; Groseth et al., 2007; WHO, 2014b). Human-to-human transmission occurs through direct contact with blood or bodily fluids of a clinically ill person or through contact with objects contaminated with the virus. In fatal cases, death usually occurs 6 to 16 days after the onset of clinical signs from multi-organ failure and shock. For EVD, the overall case fatality can range from 60 - 90%; the case fatality rate for the current outbreak in West Africa is 70.8% (WHO, 2014a). There are currently no approved therapeutics or vaccines; treatment consists primarily of supportive care.

EVD and the Natural Wildlife Reservoir

EVD is a zoonotic disease that can be transmitted to humans through direct contact with live or dead animals. Bats, both fruit-eaters and insectivores, are the suspected, yet unconfirmed, wildlife reservoir. Several wildlife species have been shown to be infected by EVD, both naturally and experimentally, including bats, nonhuman primates, duikers, mice, rats, and shrews. Ebola has been blamed for several die-off events in gorillas and chimpanzees in Central

Africa (Bermejo et al., 2006). Nonhuman primates succumb to EVD in a similar manner as humans and, thus, are not considered a classical reservoir species (Groseth et al., 2007). Morvan et al. (1999) isolated *Zaire ebolavirus* RNA from small rodents, suggesting mice, rats, and shrews as possible reservoirs. However, these findings have not been confirmed nor replicated (Groseth et al., 2007; Morvan et al., 1999). In recent years, mounting evidence points to bats as the most plausible reservoir hosts (Leroy et al., 2005; Olival & Hayman, 2014; Saez et al., 2014; Swanepoel et al., 1996). Bats have been shown to be asymptomatic carriers of *Zaire ebolavirus* antibodies (IgG) in serum samples and to have viral RNA in liver and spleen samples. Additionally, circulating *Zaire ebolavirus* antibodies IgG antibodies have been found in numerous bat populations, both in EVD endemic and non-endemic regions (Leroy et al., 2005). Based on current findings, bats are thought to be the reservoir host for Ebola viruses although other hosts may exist. Further research is needed to confirm the natural reservoir host(s).

EVD in Domesticated Animal Species

In domesticated species, dogs and pigs can be infected by EVD. In dogs, Allela et al. (2005) performed a serological survey in highly infected areas of Gabon in the 2001-2002 outbreak of *Zaire ebolavirus*. The study found evidence of *Zaire ebolavirus* antibodies in dogs though there was no evidence of clinical infection and virus was not detected in blood serum samples by viral polymerase chain reaction amplification. It remains unknown whether or not viral particles could be excreted in urine, feces, or saliva for a short period of time before virus clearance (Allela et al., 2005).

Pigs can be experimentally infected with *Zaire ebolavirus*. In a study by Kobinger et al. (2011), the pigs developed clinical respiratory symptoms, some severe, and were able to transmit the virus to naïve pen mates through direct contact. In another experimental study, infected pigs were able to transmit *Zaire ebolavirus* to macaques through indirect contact. Macaques were housed in the same room as infected pigs in open, inaccessible cages. All the macaques became infected, suggesting that aerosol transmission or aerosolized droplets in the air or on fomites may be a transmission route. Transmission from pigs to non-human primates suggests that pigs, wild or domestic, may be natural (non-reservoir) hosts for Ebola viruses and may contribute to Ebola transmission to other species, including humans, during outbreak events (Kobinger et al., 2011; Weingartl et al., 2012; Weingartl, Nfon, & Kobinger, 2013). The epidemiological significance of livestock, in particular pigs, in human EVD outbreaks is largely unknown. Further research is needed.

Pigs can also be infected with *Reston ebolavirus*, a strain that has not been shown to cause clinical disease in humans. *Reston ebolavirus* appears to result in asymptomatic infection in pigs. In 2008, *Reston ebolavirus* was isolated in the Philippines during a disease investigation in pigs. The pigs were co-infected with two other porcine viruses. Further studies found that *Reston ebolavirus* replicates subclinically in pigs; however, knowing the mutating nature of viruses, pigs could pose an unknown transmission risk to animals and people (Marsh et al., 2011).

EVD Transmissibility from Animals to Humans

Outbreaks of Ebola are thought to commence through reservoir-to-human transmission. One hypothesis is that bats transmit Ebola virus to an amplifying host, likely a nonhuman primate or a human. High viral loads in the first amplifying host favors transmission to humans, usually through direct contact with bodily fluids. This can occur with human-to-human contact or through handling infected tissues, such as through hunting and butchering nonhuman primates or bats for bushmeat (Kobinger et al., 2011; Leroy et al., 2004). Genomic surveillance suggests that the 2014 outbreak originated from a single transmission event from the wildlife reservoir to humans followed by human-to-human transmission (Gire et al., 2014). The index case for the 2014 Ebola outbreak in West Africa can be traced to a 2-year-old Guinean child playing in a hollowed out tree that housed a colony of insectivorous bats. Anecdotal evidence provided by villagers reported children often played in and around the tree, catching and handling the bats (Saez et al., 2014). The exact origin of the 2014 outbreak cannot be confirmed; however, animal reservoirs are not thought to be contributing to the continuous spread of the West African epidemic. The epidemic is being perpetuated by human-to-human transmission (Gire et al., 2014).

EVD in the United States

In the US, there have been 4 laboratory-confirmed cases of Ebola and one death. The first case of Ebola was confirmed on September 30, 2014 in a man who had traveled to Dallas, Texas from Liberia. The patient died on October 8. On October 10, a healthcare worker who provided care for the index case tested positive for Ebola. The healthcare worker owned a dog. On October 11, the dog was quarantined for 21 days. A second healthcare worker that provided care for the index case tested positive for Ebola on October 15. On October 23, 2014, a medical aid worker returning to New York from Guinea was diagnosed with Ebola. All three patients recovered and all contacts completed the 21-day monitoring period. The dog did not develop an antibody response to or clinical signs consistent with Ebola and was released after a 21-day quarantine (CDC, 2014a).

Concurrent to the US outbreak, on October 6, 2014, Spain reported its first case of Ebola in a healthcare worker that had treated a patient repatriated from West Africa. The healthcare worker owned a dog. Despite public outcry and lack of scientific evidence linking human Ebola to dogs, the Spanish government euthanized the dog on October 8 due to exposure to Ebola and fear of contagion (Brat & Bjork, 2014; Brat & Neumann, 2014).

CHAPTER IV

ONE HEALTH APPROACH TO EVD: USDA ANIMAL HEALTH PERSPECTIVE

Three culminating events triggered state and federal public health and animal health officials to come together to respond to and prepare for EVD in animals and humans: 1) the decision by the Spanish government to euthanize the dog in Spain; 2) the appearance of Ebola in the US; and 3) the uncertainty surrounding the role of dogs and pigs in the epidemiology of Ebola outbreaks. Immediately following the death of the dog in Spain, a meeting was held with several federal and state government agencies, including USDA and CDC, national health organizations such as the AVMA, and other relevant stakeholders. As a result of this meeting, the USDA One Health Joint Working Group[2] formed a task force called the USDA Ebola Working Group (WG) whose primary function was to coordinate multi-agency response activities across animal and public health disciplines. The WG was composed of leaders and subject matter experts from various USDA departmental and agency levels, government liaisons to CDC, and national health organizations. The WG had three focus areas: animal health, including livestock, companion animal, and wildlife species; public health, including food safety and occupational safety; and information sharing and research development.

In conjunction with CDC, Texas state animal and public health officials, and other relevant stakeholders, the first immediate need for the WG was to formulate the Canine Quarantine Protocol for the dog of the first healthcare worker. The protocol was successfully implemented; the dog underwent the 21-day quarantine and was released to the owner in early

[2] The USDA One Health Joint Working Group was established in 2009 to serve as a central point of coordination for discussions, reviews, and decisions regarding One Health issues. The Working Group consists of volunteers from relevant USDA agencies and offices with a core mission to raise awareness of One Health within the Department; to provide a forum for discussion One Health issues; and facilitate operational support and prioritization of tasks for One Health initiatives within USDA.

November 2014. Subsequently, the WG collaborated on various EVD response activities including providing technical information on Ebola and animals for the CDC website and public outreach; revising CDC's epidemiological questionnaire, *Ebola Viral Disease Case Information Form*, to include specific questions regarding direct contact with pets, livestock, and wildlife; developing an Ebola livestock response plan, particularly focused on swine; providing technical guidance to US government employees regarding occupational safety and health around bushmeat, pigs and pig meat; developing occupational guidelines for personal protective equipment (PPE) for US government field employees; and identifying animal-related diagnostic and research needs for EVD. A list of WG response activities is provided in Table 4.1. The list does not include the multitude of multidisciplinary and interagency communications, meetings, and logistical coordination activities that are necessary to construct and maintain the outbreak response infrastructure during One Health events. Peak activity for the WG occurred for approximately two months in the fall of 2014 during the height of the EVD outbreak in the US.

Feasibility of One Health Systems Thinking

For purposes of this paper, the evaluation of feasibility of the One Health approach refers to the degree of integration of One Health systems thinking into the USDA infrastructure. The One Health approach has been successfully implemented for a number of zoonotic and emerging diseases, including rabies, West Nile virus, Nipah, and many of foodborne bacterial pathogens such as *Salmonella* and *Campylobacter* (Monath et al., 2010; Rabinowitz et al., 2013). High pathogenicity avian influenza (HPAI) H5N1 outbreak in 2004 is perhaps an exemplar of an international, integrated One Health approach in action (Gibbs, 2014; Leischow et al., 2008). Through these disease outbreaks, it has become apparent that zoonotic, trans-boundary diseases are complex, multilayered challenges that require a wide array of disciplines and fields,

TABLE 4.1

LIST OF ONE HEALTH RESPONSE ACTIVITIES TO EVD BY FOCUS AREA

Animal Health	▪ Canine Quarantine Protocol ▪ Outreach information on Ebola and pets and other animals for the public via CDC website ▪ USDA APHIS VS Ebola Virus Disease Livestock Response Plan ▪ Companion animal confinement and quarantine plans - *Interim Guidance for Public Health Officials for Ebola Contacts with Pets* - *Interim Protocol for dog or Cat Confinement after Exposure to a Human with Confirmed Ebola Virus Infection* ▪ Factsheet regarding Ebola and wildlife intended for use in zoos and other similar establishments ▪ Factsheet regarding Ebola and swine intended for USDA agency and industry use
Public Health	▪ PPE guidance documents for US government employees and other animal health personnel ▪ Technical guidance to US government employees regarding occupational safety and health and contact with bushmeat, pigs, and pig meat ▪ Outreach materials to the public regarding Ebola transmission ▪ Outreach materials to the public regarding the health risks and illegality of bushmeat ▪ Revision of CDC's epidemiological questionnaire, *Ebola Virus Disease Case Information Form*, to include specific questions about direct contacts with pets, livestock, and wildlife
Information Sharing & Research Development	▪ Animal diagnostic testing protocols and capabilities ▪ Ebola-related import policies for animals, animal (by-) products, and animal research samples ▪ Animal-related EVD research needs, including further studies of the epidemiology of Ebola in domesticated species and validation of diagnostic testing in domesticated species ▪ Emergency management and occupational safety training for US government employees ▪ Responses to Congressional inquiries for animal-related Ebola information ▪ Responses to international requests for information ▪ Regular situational reports for the White House and USDA agencies ▪ Decision Memorandums, information Memorandums, briefings, and talking points for USDA leadership ▪ Presentations at scientific meetings and conferences for industry and stakeholders

including shared surveillance, diagnostic, and research networks as well as communication and informatics infrastructures so that governments and organizations can prepare and respond effectively (Leischow et al., 2008).

Systems thinking is the idea that complex problems are best solved by considering the non-linear relationships and feedback loops between the components that make up the whole (Zinsstag et al., 2011). Working in isolation or within single-sector silos is less effective than creating integrated frameworks in which all the parts can be considered together. Systems thinking emphasize knowledge-sharing across disciplines; network-centric thinking that encourages relationship-building across disciplines and across organizations; and systems (re)organizing to foster improvements in organizational structures and functions (Leischow et al., 2008).

The One Health approach embodies systems thinking. However, integrated One Health frameworks cannot be implemented overnight; thus, creating the organizational infrastructure with strong cross-sectoral relationships takes time and resources and must be well-established before disease events occur. Making the paradigm shift from a reductionist approach to a more holistic, network-centric approach takes trial-and-error with real-life scenarios. Without a validated evaluation method for systems thinking approaches, outbreak events are often the only means to evaluate how well these systems are working and to illuminate vulnerabilities in the system.

For the EVD outbreak in the US, several key components of the systems thinking approach for One Health were in place at the USDA level. For example, USDA has the One Health Coordination Center (OHCC) within USDA, Animal and Plant Health Inspection Service (APHIS), Veterinary Services (VS) which provides US leadership for the animal health component of One Health (USDA APHIS, 2014). Additionally, the One Health vision and its principles have been incorporated into strategic plans and the organizational structure (USDA APHIS, 2015). USDA has committed to collaborating with both internal and external partners, including entities that encompass human, animal and environment health such as federal agency partners, international organizations, non-government organizations, industry stakeholders, and academic institutions. Inter-departmental liaison positions for One Health-related issues are present including an OHCC liaison position within the CDC. Additionally, many US government departments, including USDA, have committed to the Global Health Security agenda which partners with other nations and international organizations to prevent, detect and respond to disease outbreaks that affect the global community (DHHS, 2015). Thus, USDA has the infrastructure and the network connections, internally and externally as well as domestically and internationally to make the systems thinking approach a feasible mechanism for addressing One Health events.

However, the EVD outbreak uncovered several vulnerabilities to the One Health approach. Because the role of animals in the epidemiology of EVD has yet to be defined and its appearance in the US was unprecedented, there was initial uncertainty as to the role USDA and APHIS VS OHCC should play in the animal health response. Foreign animal diseases such as foot-and-mouth disease or avian influenza have very distinct federal response plans that have been practiced and executed; thus, inter-agency and intra-agency roles and responsibilities are defined. In contrast, EVD presented a gray area for leadership. This was further compounded by its high profile nature in the media and sensitivities by the Department, agricultural industries, and others to avoid misinformation to the public about the role of livestock, particularly pigs, which, like H1N1 influenza pandemic in 2009, could potentially undermine customer confidence in pork products and economically depress pork producers. Leadership and coordination of tasks of the WG was eventually shared between APHIS VS OHCC at the agency level and the USDA Office of Homeland Security and Emergency Coordination (OHSEC) at the departmental level. Communications, both external and internal to the department, and coordination of technical guidance documents were funneled through the WG to maintain consistency of the USDA position and messaging.

Other vulnerabilities were identified in informatic systems, including the efficacy of information technology (IT) tools and information sharing. Network securities and computer firewalls limited access to web applications such as SharePoint, making it difficult for WG members external to USDA to access reports and technical documents. Distribution of information to the WG was primarily through email distribution lists; however, the IT system protocols to add members to the WG email distribution list was slow and inconsistent, often taking days to complete requests. With the EVD situation changing daily, sometimes hourly, this meant that vital information was not reaching WG personnel in a timely manner, potentially hindering EVD response activities. Because this was a multi-agency approach, clearance of technical documents and guidance had to go through the approval process of multiple agencies and departments. This can be a laborious bureaucratic process in a single-sector approach; in the One Health approach, it is further compounded by multiple agency level and departmental approval processes, often performed in sequence rather than simultaneously. The sluggish flow of information stifled both inter-agency and intra-agency communication efforts. Lastly, because of the sheer size of the US government, it was difficult to track all the EVD response activities. This was particularly apparent in the development of PPE technical guidance. Several US government departments and agencies as well as non-government organizations and industries were concerned about PPE for employees; thus, multiple efforts to provide PPE guidance for EVD were occurring simultaneously. To avoid duplicate efforts and inconsistent or conflicting guidance, it was important to identify the key players and subject matter experts to ensure open, frequent communication for coordination of tasks.

Multi-Disciplinary Integration of the USDA One Health Approach

A comprehensive One Health approach integrates animal, human, and environmental health and considers communication and collaboration functions among all 3 sectors into the system infrastructure. Multi-disciplinary integration refers to the extent to which all three components were included into the One Health response efforts. For the USDA WG, multidisciplinary integration was good with several key components of One Health present. Because this was USDA-led effort, animal health for livestock was well-represented on the WG by numerous APHIS VS personnel with expertise in various livestock issues. Animal health for companion animals, including exotic pets such as pot-bellied pigs and nonhuman primates, was represented to a much smaller degree primarily through indirect efforts and communications through CDC and AVMA. Human health, or more specifically public health, was represented by various facets of USDA and Department of Health and Human Services. The Food Safety Inspection Service (FSIS), the Food and Drug Administration (FDA), and liaison representation for United States Department of Homeland Security, Customs and Border Protection (CBP) port inspectors provided subject matter experts and dedicated liaisons to the WG to cover issues that affect both US government employees that may potentially handle EVD-exposed livestock or bushmeat and for public health concerns surrounding bushmeat and the consumption of pork. Additionally, in conjunction with CDC, the WG addressed public health messaging to the general public regarding the health concerns of bushmeat and the illegality of bringing bushmeat into the United States. For environmental health, limited representation within the WG was present for wildlife and zoo animals through the APHIS units of Wildlife Services and Animal Care. It's important to note that several agencies or offices within the WG provided input across both multiple sectors of animal, human and environmental health.

Several One Health components within the WG were underrepresented or absent. Although the WG had access to government regulatory environmental agencies, namely the Environmental Protection Agency, field and epidemiological components of environmental health were limited. Although EVD transmission for this outbreak was primarily human-to-human, technical expertise from environmental health professionals could augment response plans and research priorities. For human health, the clinical practice (i.e., physicians and representation by the AMA) component for human medicine was absent from the WG. This was likely due to the overwhelming need for physicians and human health organizations to be focused on the human aspects (prevention of spread, treatment protocols, hospital preparedness, etc.) of the EVD outbreak. Additionally, input from biomedical researchers from the human medicine side for potential research collaborations at the human-animal-environment interface was limited. Many of the limitations of One Health integration in the WG stem from the origins of the efforts; namely, as an internal task force within USDA to address animal health issues around EVD. The WG had to rely on pre-existing relationships and networks to get multidisciplinary and multiagency integration and representation. Additionally, representation and integration of One Health components were limited by the authoritarian power of federal agencies and offices[3], conflicting resources and agendas, and the availability and necessity of volunteer representation for the WG.

Benefits of the One Health Approach to EVD

The fundamental goal of the One Health approach is to improve the overall health and well-being of animals, humans, and the environment. One Health is based on the systems thinking that holistic consideration of the interactions of the individual parts leads to better understanding and improvement of whole health. Thus, tangible benefits from the USDA WG could provide validity for the One Health approach at the federal level. Several key outcomes from the One Health approach lend credence to this. First, the collaborative efforts to quarantine the dog of the first infected healthcare provider saved the life of that dog and future companion animals that may have contact with EVD-infected humans. Furthermore, in developed nations where the human-animal bond is strong and companion animals are considered members of the family, the creation and implementation of the Canine Quarantine Protocol avoided public outcry and helped to maintain public confidence in the EVD outbreak response. Secondly, animal health input into CDC's epidemiological questionnaire, entitled *Ebola Virus Case Investigation Form*, provided a means to evaluate any direct link between human EVD contacts and animals. The questionnaire was expanded from inquiring solely about pets (dogs and cats) to including questions that asked about contacts with livestock, wildlife, and other animals. This strengthened cross-sectoral communications and collaborations, ensuring that animal health officials at the local, state and federal levels are notified at the earliest indication that animal exposure of any kind has occurred. Thirdly, the WG identified animal-related research needs for EVD. In particular, further research is needed to confirm natural reservoir hosts and to understand the

[3] For example, USDA APHIS has authority over livestock health and protecting agricultural resources from wildlife damage while CDC has authority over companion animals, specifically communicable human diseases related to the importation and movement of dogs, nonhuman primates, and some reptiles.

epidemiological role of animals, particularly pigs. Animal health input into research needs is important as resources are limited and collaborative efforts can be economically beneficial when research funding and laboratory resources (i.e., accessibility to biosafety level 4 labs) are scarce. Lastly, many of the EVD response activities by the WG were preparatory efforts for future EVD outbreaks and similar zoonotic and emerging infectious diseases. It strengthened existing response frameworks by encouraging the WG to review current networks and protocols. For example, the EVD outbreak elicited renewed discussion among the WG about the public and animal health concerns of imported, illegal bushmeat. It prompted a thorough review of current PPE protocols and the national veterinary stockpile capabilities for foreign animal diseases; both deemed to be appropriate and applicable to an EVD outbreak involving animal species. Most importantly, the EVD outbreak stretched our thinking beyond the standard, everyday regulatory diseases of animal health (i.e., bovine tuberculosis, avian influenza, BSE, and others) toward the ever-increasing occurrences of emerging infectious diseases where epidemiological knowledge is incomplete and the lines between the human-animal-environment interface are blurred.

Discussion

The 2014 EVD outbreak in the US tested the One Health infrastructure at the federal level for animal health. It confirmed that USDA has the infrastructure and the network connections to make the systems thinking approach a feasible mechanism for addressing One Health events. However, gaps exist for clearly defined roles and responsibilities for leadership and participatory players and the efficacy of IT tools and information-sharing systems need improvement to better accommodate a network-centric, multi-disciplinary system that can keep pace with rapidly-changing disease outbreak situations. The EVD outbreak highlighted the degree of integration of animal, human, and environmental health disciplines. Understandably, animal health was well-represented within the USDA WG and animal health issues for livestock and companion animals were well covered. For human health, the clinical practice component of human medicine was largely absent and aspects of environmental health were absent or underrepresented. Despite these shortfalls, the One Health approach proved to be advantageous both for USDA as well as for overall (animal) health. It provided technical support and guidance for the Canine Quarantine Protocol, directly affecting the health outcome of the dog of the infected healthcare worker and future companion animals of infected patients. It created new collaborative networks and strengthened existing network relationships across animal and public health. It encouraged preparatory efforts for the next emerging infectious disease event, stretching the traditional views and constructs of USDA's role in One Health events and better preparing the Department and its agencies for the next EVD or similar outbreak.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The One Health approach to zoonotic and emerging infectious diseases has historical roots dating back to the 19th century. It is an evolving concept that has experienced a recent resurgence. Although a wide-ranging commitment to One Health has been achieved, the translation of ideas into practical use has been challenging. Professions are siloed and some are skeptical of a holistic approach; thus, integration across some disciplines has been slow. The lack of operationalization of One Health may be due to its broad definition, making it difficult to articulate the One Health agenda and identify specific actions. Most examples of One Health successes and funding have been tied to specific diseases (i.e., avian influenza), making it difficult to identify effective ways to support the interdisciplinary nature of One Health in the absence of a specific disease focus and in times when resources are scarce (Gibbs, 2014). Also, evaluation methods for validation of the One Health approach are limited. Large, controlled studies on One Health disease prediction, control, and intervention strategies using shared surveillance data and economic cost-benefit analyses may provide quantitative evidence for One Health systems thinking and may help push One Health into the mainstream (Gibbs, 2014; Rushton, Hasler, De Haan, & Rushton, 2012).

It is not a matter of “if” but rather “when” the next zoonotic or emerging infectious disease will occur in the United States. Several key recommendations have been made to better prepare for future One Health events. An educated public health workforce is vital to providing well-trained professionals and able leadership. Many veterinary and medical schools are already offering dual-degree programs in (veterinary) public health (Howell, Hamilton, New, Lane, &

Brace, 2008). Many have suggested that schools of public health as well as veterinary and medical schools should offer master's and doctoral level degree programs in One Health (Kahn, 2011). Students and existing professionals in healthcare specialties, including animal, human, and environmental health, need training in multidisciplinary approaches to emerging infectious diseases, comparative medicine and biomedical research, public health, global food safety and security, and ecosystem and environmental health. Educating professionals as well as the general public about One Health methods and benefits can help to further permeate the concepts towards universal recognition and acceptance (Dhama et al., 2013; Gibbs & Gibbs, 2013; Gibbs, 2014; Mazet et al., 2009).

Continued communication and collaborations must occur between veterinarians, physicians, and environmental health professionals regarding animal, human, and wildlife health. This can be accomplished, for example, through jointly sponsored veterinary and medical conferences on zoonotic and emerging infectious diseases or through cross-sectoral liaison positions (i.e., veterinarians in public health offices), bringing together local, State and federal counterparts of animal and public health. Also, integrated, trans-boundary surveillance systems across species can bring together participants from diverse scientific backgrounds and help to identify infectious disease risks to human and animal populations (Dhama et al., 2013; Rabinowitz et al., 2013). Fostering relationships across disciplines leads to a network-centric culture and (re)organization of traditional infrastructures towards One Health systems thinking, creating opportunities for collaborative, cooperative and coordinated efforts during One Health events. Interactions that help to build relationships and collaborative networks can help to ensure a more rapid response to zoonotic and emerging infectious disease outbreaks (Kahn et al., 2007).

Many propose that veterinarians are best suited to lead the One Health movement. Much of the impetus for One Health has come from the animal health side with veterinarians, academia, governments, and international organizations demonstrating the strongest commitment to the approach (Burns, 2012; Lee & Brumme, 2013). Veterinarians are educated in multiple species, comparative medicine, and herd health with a focus on protecting and improving both animal and human health. They have an in-depth, herd-level understanding of biological systems, disease pathology and epidemiology, diagnostic methods, and treatment and disease management protocols for infectious diseases. Through their education and vocation, they have a fundamental connection to food animals and food safety, often coming in contact with a wide variety of domestic and wild animals and often with established networks to regional and national diagnostic laboratory systems and local and national regulatory systems for animal health, food safety, and public health. Because of this, veterinarians are well poised to provide the bridge between animal, human, and environmental health (Kahn et al., 2007; Osburn et al., 2009).

As the agency with authority over the protection and promotion of animal health, USDA APHIS is in the strategic position to continue to lead the One Health movement at the federal level. USDA APHIS has begun integrating One Health systems thinking into its infrastructure and it has the educated workforce in both veterinary medicine and public health that is needed to provide precise leadership and strong staff support. The agency has established network relationships with various sectors of One Health, including animal health, food safety, wildlife health, and public health. The One Health approach from the animal health perspective proved to be an appropriate strategy for responding to the EVD outbreak in the United States. With continued integration of One Health principles and implementation of flexible, cross-sectoral networking and governance, current and future challenges – bioterrorism, antimicrobial drug resistance, climate change, or the yet to be discovered zoonotic and emerging infectious diseases – will benefit from the One Health approach as well.

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