Investigation of the Factors Causing the Complexity of the Ongoing West African Ebola Virus Epidemic

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Acknowledgments

First and foremost I would like to thank my parents for providing me with all of the tools that I have needed to succeed in college. They always push me to do my best and not accept failure. Their financial support has allowed me to go to the university of my choice and to follow my dreams by studying abroad. Their emotional support has helped me pull through some difficult times and end my career at OSU on a high note. I would not have been able to do well in the Honors College, or college in general, without them.

I would not have been able to write this honors thesis without the help of my thesis advisor, Dr. D. Kim Burnham, and my second reader, Dr. Earl L. Blewett. Dr. Burnham is so kind and has been extremely helpful throughout the thesis writing process. He listened to all of my concerns and provided me with excellent advice and research tips. In addition, he is an excellent professor and has made immunology a very interesting subject to learn about. Dr. Blewett works in Tulsa, so I would especially like to thank him for coming to Stillwater to meet with me and watch my thesis presentation. His extensive knowledge of viruses and Ebola was of immeasurable help to me. He has always been able to point me toward new Ebola articles and provided lots of constructive comments about my thesis. He is also an excellent professor and his virology class has been one of my favorites.

Finally, I would like to thank my work supervisor, Sarah Coates. Sarah read my thesis and helped me fix all of my grammatical errors. Having someone from a non-science background read my thesis was a great way to get a new perspective on it. I would also like to thank her for being such a wonderful supervisor for the last four years.

Abstract

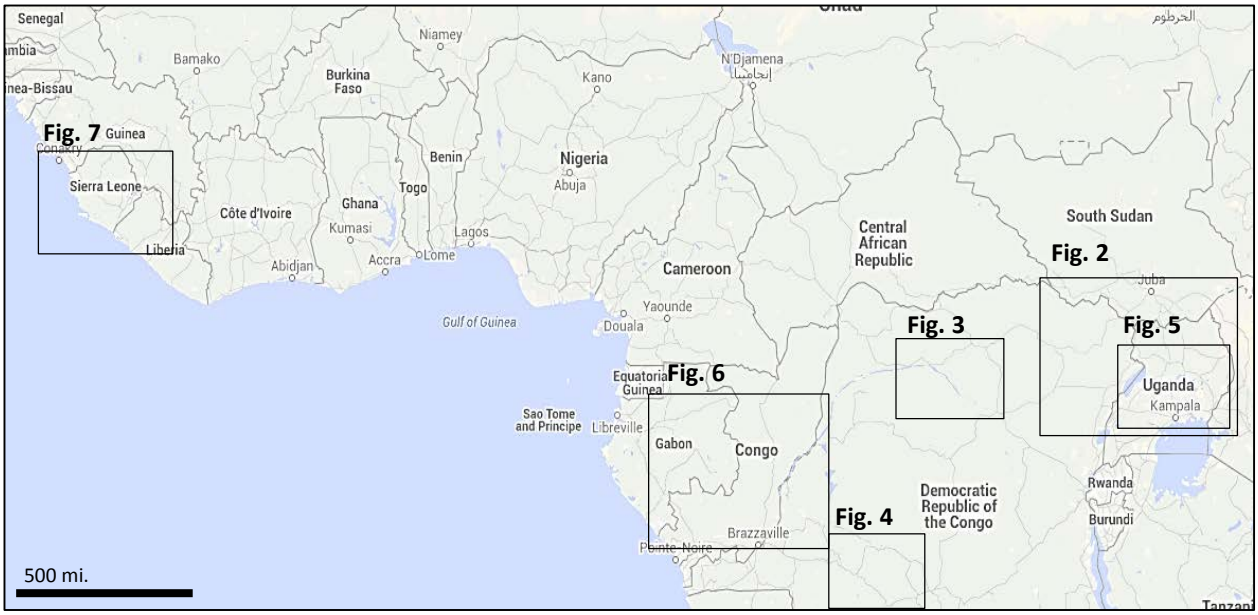
Ebola virus disease is a hemorrhagic fever characterized by flu-like symptoms, internal and external bleeding, and quick onset of death in many victims. It was first identified in simultaneous outbreaks in Sudan and Zaire in 1976, and since then it has caused numerous small outbreaks and a few large ones. The largest outbreak to ever occur is still ongoing, with over 26,000 cases and over 11,000 deaths observed in the West African countries of Guinea, Liberia, and Sierra Leone. No previous outbreak has ever been so large, prompting many to question what exactly has caused this outbreak to become so large and complex. Because it is currently assumed that genetic changes in the strain causing this outbreak are not the cause of the size of the outbreak, the public health responses to each outbreak, cultural differences in each location, and the characteristics of the physical location of each outbreak were researched in order to determine if any difference in one of these variables could be behind the complexity of the current outbreak. Evidence indicates that poor public health infrastructure and spending, an inadequate initial international response, a lack of familiarity with Ebola in West Africa, and the proximity of the initial outbreak location to multiple capital cities allowed the virus to spread to and throughout numerous large cities while going undetected for almost three months, causing the outbreak to explode before officials had the chance to control it.

List of Figures and Tables

Introduction

Ebola virus disease (EVD), or Ebola hemorrhagic fever, is an illness caused by members of the viral genus *Ebolavirus*. The virus targets immune cells and the endothelial cells that line blood vessels, leading to flu-like symptoms, diarrhea, liver and kidney problems, and sometimes internal and external bleeding. The virus is spread through direct contact with the bodily fluids of an infected person. There are currently no antiviral drugs or vaccines available to directly combat the virus, so simple supportive treatments such as rehydration and blood transfusions are the only ways to treat the illness. The mortality rate of the disease usually ranges from 25%-90%, with different strains of the virus generally causing distinctly different rates (CDC, 2014). There are five viral strains in the *Ebolavirus* genus, four of which cause disease in humans: Sudan, Zaire, Bundibugyo, Taï Forest, and Reston, the latter of which only causes disease in non-human primates. The reservoir of the virus has not yet been confirmed, but it is suspected that several species of fruit bats often hunted as bush meat are the most likely candidates. Aside from the Reston strain, the virus is indigenous to Central Africa, where all but one of the outbreaks have occurred (Fig. 1).

Figure 1. Central and West Africa.[1]



The boxes contain the areas pictured in Figures 2, 3, 4, 5, 6, and 7.

The first known outbreaks of the disease occurred almost simultaneously in 1976 in areas that are now part of South Sudan and the Democratic Republic of the Congo (DRC), formerly Zaire. The 2014-2015 West African Ebola virus epidemic is the worst outbreak of the disease in history. To date, over 26,000 people have been infected and over 11,000 people have died, mostly in Liberia and Sierra Leone. The Centers for Disease Control and Prevention (CDC) estimate that there may be up to two to three times as many unreported cases (Meltzer, 2014). Although it may seem like common sense that an untreatable virus would cause so much damage in developing countries, no previous outbreak has ever caused the death of more than 300 people. Although there are several hypotheses about why the ongoing outbreak has become so massive, it is still an interesting question to explore. The most obvious culprit for the increased severity of this outbreak is some sort of change in the genetic makeup of the virus.

[1] (Google Maps, 2015a)

While this is a good assumption since viral genomes change quite easily, it does not appear to be correct in this case. Gire et al.'s sequence of the genome of the strain involved in the current outbreak shows that there are some differences from previous epidemic strains, but, while it is still technically unclear whether or not these differences could account for the size of this outbreak, there are no signs that this is the case (Gire et al., 2014). Since it seems unlikely that genetic differences between strains are causing this outbreak's severity, this paper will focus on other possible factors. Factors that will be discussed include differences in public health responses in each outbreak's location, cultural differences in the areas of the outbreaks, and differences in the physical location of each outbreak.

Outbreak History

Table 1. Summary of Ebola outbreaks with more than 100 reported deaths[2]

Date	Location	Viral Species	Reported Cases	Reported Deaths (%)
1976	Sudan (South Sudan)	Sudan	284	151 (53%)
1976	Zaire (DRC)	Zaire	318	280 (88%)
1995	Zaire (DRC)	Zaire	315	250 (81%)
2000-2001	Uganda	Sudan	425	224 (53%)
2002-2003	Republic of the Congo (RC)	Zaire	143	128 (89%)
2007	DRC	Zaire	264	187 (71%)
2014-Present	Liberia, Guinea, Sierra Leone	Zaire	26628	11020 (41%)

EVD first emerged in late summer in 1976 in the central African countries of Zaire and Sudan. The first identifiable victim of the illness was a factory worker from Nzara, a Sudanese

[2] (CDC, 2014)

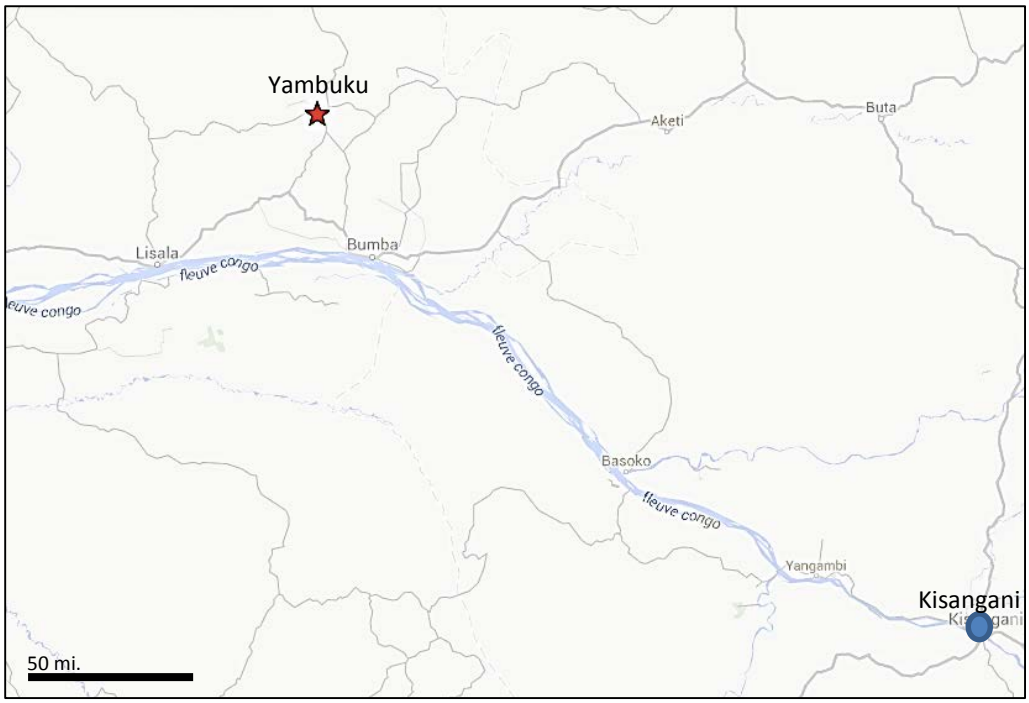
village near the Zairian border (Fig. 2), who died on July 6, 1976, one week after being admitted to a hospital (WHO, 1978a). The victim walked through a forest to get to his job everyday, so it is possible that he contracted the illness from an animal he came into contact with there. There were 284 reported cases and 151 reported deaths in Nzara and surrounding areas (Table 1).

Figure 2. Map of Nzara, South Sudan, the location of a 1976 outbreak.[3]

In early September a new outbreak began in Yambuku, Zaire, a small town approximately 500 miles from Nzara (Fig. 3). The outbreak centered around the Yambuku Mission Hospital, where nurses apparently did not properly disinfect the five needles a day they were given to use (WHO, 1978d). The outbreak ended with 318 reported cases and 280 reported deaths and a much higher mortality rate than the outbreak in Sudan (Table 1).

[3] (Google Maps, 2015i)

Figure 3. Map of Yambuku, DRC, the location of a 1976 outbreak.[4]

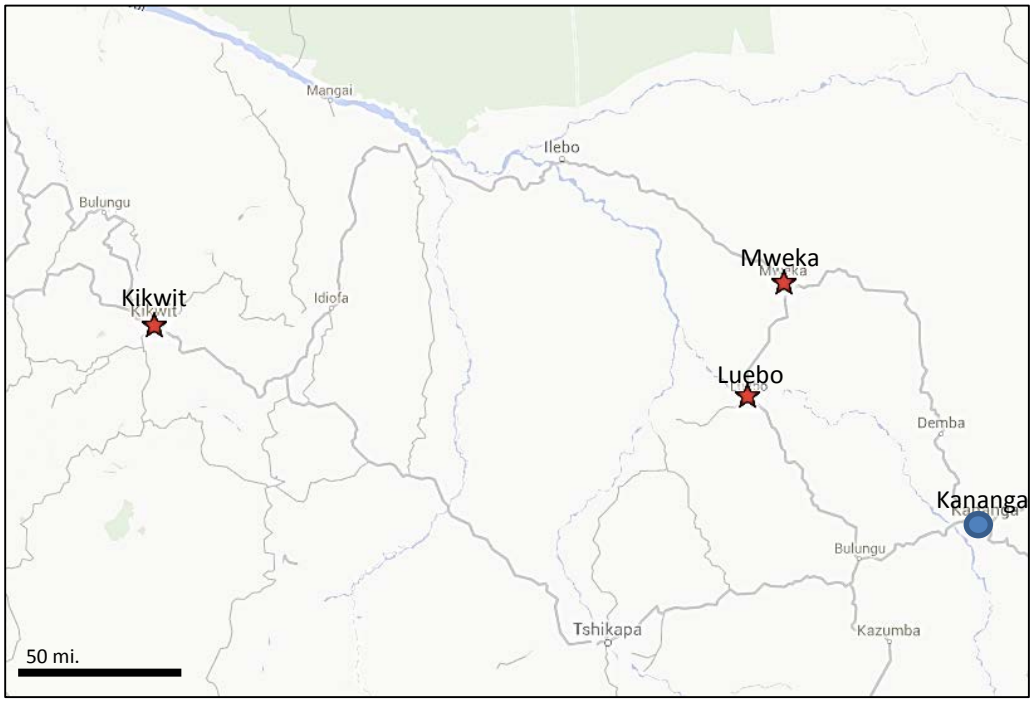


Both outbreaks were contained before the end of the year through the isolation of patients and use of full body protective gear by healthcare workers. In both outbreaks, it was noted that hospitals using improper precautionary procedures were the major contributors to the spread of the illness throughout the community. Both patients and healthcare workers at the hospitals were at high risk for infection due to inadequate training and supplies. Because of the often-severe nature of hemorrhagic fevers, scientists were quick to obtain samples from the first victims and isolate the virus. It was originally believed that the outbreak was possibly caused by something in the *Marburgvirus* genus (Pattyn, Groen, Jacob, Piot, & Courteille, 1977), but antigenic differences led scientists to later conclude that although the virus belonged to the same family as *Marburgvirus*, it was a distinct new virus, later named after the Ebola River (Johnson, Lange, Webb, & Murphy, 1977). Scientists were also initially unsure about any links

[4] (Google Maps, 2015m)

between the two outbreaks, although it was generally believed that they were somehow connected (WHO, 1978a). However, it was later determined that two separate strains (Sudan and Zaire) caused the outbreaks.

Figure 4. Map of Kikwit, DRC, the location of the 1995 outbreak, and Mweka and Luebo, DRC, the locations of the 2007 outbreak.[5]

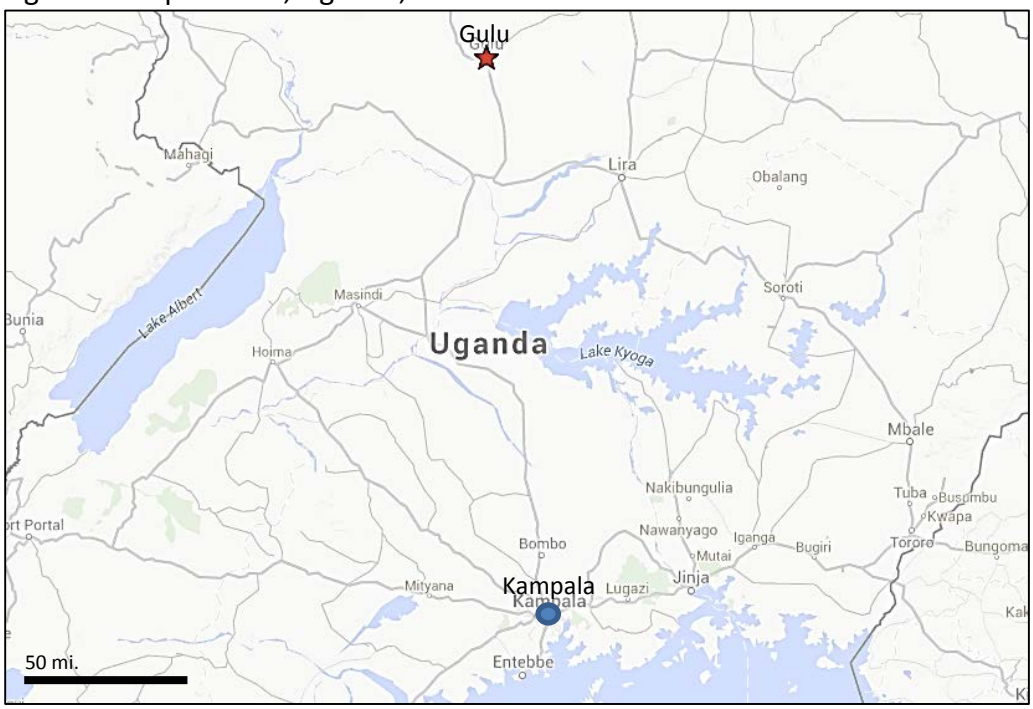


The next major outbreak of the disease occurred almost 20 years later in 1995 in the city of Kikwit, Zaire, a large city in the southeast corner of the country (Fig. 4). The first confirmed case of the illness was a laboratory technician from Kikwit General Hospital who was admitted to the hospital in early April, although it is believed that the true index case was a charcoal worker who died from a hemorrhagic illness in mid-January (Muyembe-Tamfum, Kipasa, Kiyungu, & Colebunders, 1999). Like the previous outbreaks in Zaire and Sudan, this outbreak had a significant number of nosocomial transmissions and many of the victims were healthcare

[5] (Google Maps, 2015e)

workers. Because of this, all hospitals in Kikwit and the surrounding area were essentially shut down in order to prevent nosocomial transmission (Muyembe-Tamfum et al., 1999). The outbreak ended in mid-July, with a total of 351 cases and 250 deaths (Table 1).

Figure 5. Map of Gulu, Uganda, the location of the 2000-2001 outbreak.[6]

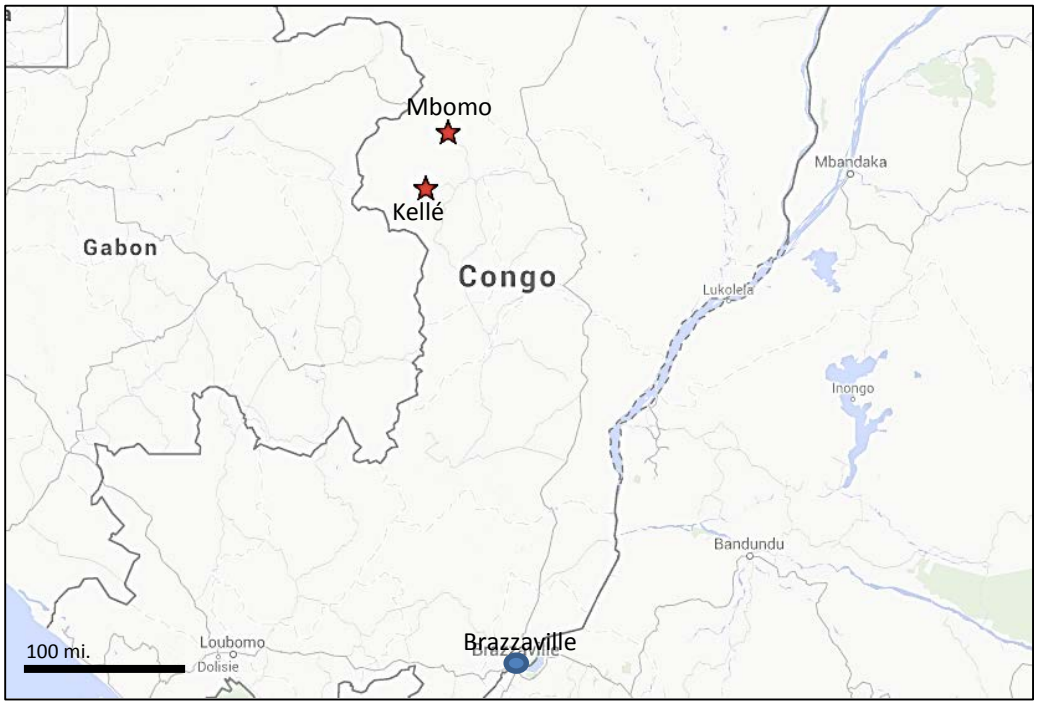


The first ever outbreak to occur in Uganda began in early October 2000 in the Gulu District, a northern area near the Sudanese border (Fig. 5). The identity of the index case is not clear, but it seems as though the first few cases possibly developed as a result of a funeral in a small village, Rwot Obilo, not far from the city of Gulu (Lamunu, 2002). From there, it spread to other small villages, but its main impact was in the city of Gulu itself. Lacor Hospital, a private institution, was the first hospital to receive Ebola patients, and as such became the de facto center of the outbreak, although Gulu Hospital also had a significant number of cases (Lamunu,

[6] (Google Maps, 2015c)

2002). As in previous outbreaks, the Ugandan outbreak had a significant number of cases involving healthcare workers who contracted the illness because of improper protective protocols. Intense efforts by the Ugandan government and the World Health Organization (WHO) to educate the community on how to stop transmission proved successful, and the outbreak ended in January 2001 with a total of 425 cases and 224 deaths (Table 1).

Figure 6. Map of Kellé and Mbomo, RC, the locations of the 2002-2003 outbreak.[7]



The next major outbreak to occur began in December 2002 in the forests around Kellé and Mbomo, RC, eastern cities near the Gabonese border (Fig. 6). Large numbers of chimpanzees and gorillas were the first victims of the outbreak, and it is likely that contact with one of the dead animals cause the first human case (Masland, 2003). There were three separate points of introduction of the virus into the community, each of which was related to

[7] (Google Maps, 2015g)

contact with dead animals prior to infection (WHO, 2003). The first human deaths occurred in mid-January in Kellé and travellers soon imported the virus to Mbomo. Unlike previous outbreaks, nosocomial transmission did not play a major role. Only three healthcare workers became infected and most transmission was intra-familial (WHO, 2003). This indicates that there was a high level of preparedness and organization present in hospitals, most likely because a smaller outbreak in RC had ended just a year previously. The outbreak was declared over in early June, although transmission ended in April. A total of 143 cases and 128 deaths were reported (Table 1).

The last major outbreak to occur before the ongoing one occurred in late 2007 in the area around Luebo and Mweka, DRC (Fig. 4). The first few cases occurred within a cluster of villages along a road connecting the two cities, with the index case most likely being a 55-year-old woman who died in early July (Leroy et al., 2009). A fruit bat migration had recently left the area, so it is assumed that contact with an infected animal is what caused the outbreak. The illness spread throughout the villages, known as the Kampungu agglomeration, but because of their relative isolation, it went unnoticed until late August. The illness mostly stayed in the villages and intra-familial transmission was the most common type of infection. Nosocomial transmission was not a major contributor since the medical centers set up near the villages were run by adequately trained international teams. The outbreak was declared over on November 20, with the last case being diagnosed in early October (Kaput, 2007). The outbreak ended with 264 reported cases and 187 reported deaths (Table 1).

Figure 7. Map of Meliandou, Guinea, the location of the 2014-2015 outbreak.[8]

The ongoing outbreak began in December 2013 when a two year old boy named Emile Ouamouno died from a hemorrhagic illness in Meliandou, Guinea on December 6, shortly after he had been seen playing near a tree inhabited by bats (Yan, 2015). Meliandou is a small, southeastern village near the Sierra Leonean, Liberian, and Ivorian borders (Fig. 7). Multiple members of the boy's family died soon after he did and the illness spread throughout the village and on to larger cities. Ebola had not previously caused an outbreak in West Africa, so health officials did not initially regard it as a possible diagnosis. This meant that the outbreak was not confirmed as being caused by Ebola until three months later in March 2014 (BBC, 2014). By the beginning of April, the illness had spread to Sierra Leone and Liberia, both of which have experienced much greater transmission than Guinea. The capitals of all three countries (Conakry, Freetown, and Monrovia) have all seen significant numbers of cases, as

[8] (Google Maps, 2015k)

have areas along the borders between the countries. The outbreak has also seen a small number of cases in Nigeria, Senegal, Mali, Spain, the United Kingdom (UK), and the United States of America (US). In October, two nurses contracted the illness from a patient being treated in Dallas, Texas, marking the first transmissions to occur outside of Africa. These transmissions indicate that first-world hospitals are still not as well equipped to handle Ebola, as some would assume. Like most previous outbreaks, the current one has seen a large number of cases among healthcare workers and foreign aid workers. Because Ebola was not previously a concern in the region, many of these professionals had no idea that they were potentially putting themselves at risk. Transmission has ended in Liberia and has begun to slow in Guinea and Sierra Leone, so it is possible that the outbreak will end soon (WHO, 2015a). There are several experimental anti-viral drugs and two Ebola vaccines currently in the trial phase that could potentially bring the outbreak to an end if need be (WHO, 2015c), although it appears that it may come to an end without these aids. As of May 6, 2015 there have been 26,628 reported cases and 11,020 reported deaths (Table 1).

Differences in Public Health Reponses

The strength of a country's public health infrastructure can greatly influence the course of an outbreak of an infectious disease. Differences between public health systems in different countries may help explain the complexity of the current Ebola outbreak. In addition, the efforts of major international public health groups such as the WHO can help sway the course of an outbreak. Since the first incidences of the illness in 1976, international groups have been

essential in curbing Ebola outbreaks, so a difference in their responses could help explain the magnitude of the current outbreak

Table 2. Public health expenditure of Ebola affected countries[9]

Date	Location	Public Health Expenditure (% GDP)
1976	Sudan	N/A
1976	Zaire	N/A
1995	Zaire	0.2
2000-2001	Uganda	2.1
2002-2003	RC	1.3
2007	DRC	1.2
2014	Guinea	1.7
2014	Liberia	3.6
2014	Sierra Leone	1.7

If a difference in public health spending was the main factor behind the enormity of the current outbreak, it is logical to assume that the countries involved in this outbreak would have less spending than those involved in previous outbreaks. However, Table 3 shows that this is clearly not the case. Although there is not data available for Zaire and Sudan from 1976, both countries were just emerging from or just entering into periods of political turmoil, so it is safe to assume that their spending was not very high. Guinea currently has spending that is about the same as countries involved in several other outbreaks, and Liberia and Sierra Leone both

[9] (World Bank, 2015)

have reasonably higher spending than seen in any other outbreak. However, compared to developed countries, these numbers are still incredibly low. For example, in 2012 the United States spent 8.1% of its GDP on public health, over twice the amount that Liberia spent (World Bank, 2015). Reports of low supplies of gloves and soap in Liberian hospitals (Forrester et al., 2014) bring to mind the five needles per day used by nurses in Zaire in 1976 (WHO, 1978d). Although the illness was transmitted within the United States, the fact that only two people became ill shows the difference that more public health spending can make in stopping an outbreak. The extremely low amount of public health expenditure in the countries currently affected by Ebola clearly played a role in the complexity of the outbreak, although there are other factors at play since the expenditure numbers are not radically different from those observed in previous outbreaks.

While more public health spending is generally better, there are low-cost things that governments can do to help stop an outbreak, but the success of these methods depends on how quickly the outbreak is recognized. If a disease has never been seen before in a country, most public health officials and doctors will be unfamiliar with it and will initially diagnose it as an endemic illness that they are familiar with. Diseases such as malaria and dengue fever are extremely common in West Africa and their initial symptoms greatly resemble those of Ebola. Ebola had never been observed in West Africa before the current outbreak, so doctors there very easily misdiagnosed patients and did not have the correct diagnosis until it was too late to do anything. The longer the illness goes undiagnosed, the more people are infected and the more difficult the outbreak becomes to get under control. It took the current outbreak three

months to be recognized, by which point it had killed almost 60 people and had made it to the capital of Guinea (BBC, 2014). Only one other major outbreak took as long as the current one to be recognized, although since it was in a country that had already experienced Ebola, this was most likely due to geographical isolation and not a public health failure. The current outbreak essentially stands alone in the amount of time that it took to be recognized, indicating that the unfamiliarity of public health officials with Ebola, contributed greatly to the complexity of the outbreak.

The WHO is an agency of the United Nations (UN) devoted to promoting public health around the world. When outbreaks of serious infectious diseases, like Ebola, occur in developing countries, the WHO often plays a major role in helping to bring the outbreak under control. It helps national governments perform surveillance, run social mobilization campaigns, and fortify healthcare facilities with volunteers. The national government must request assistance from the WHO before it will actually mount a response and the request is generally only made once the government has confirmed through testing, or has other very strong evidence of, the presence of Ebola. Because of the potentially severe nature of Ebola outbreaks, the WHO usually sends an initial team to begin surveillance within a few days of receiving a request for assistance. During the first two outbreaks in 1976, the WHO's function was somewhat limited due to the fact that they did not know exactly what they were dealing with. However, through surveillance and observation they were able to come up with guidelines for future outbreaks (WHO, 1978a, 1978d). In subsequent outbreaks the WHO focused not only on surveillance, but also community engagement. In countries with poorly

developed public health infrastructures, educating people on how to stop transmission is sometimes the best way to curb the outbreak. WHO social mobilization campaigns usually involve promoting safe, dignified burials; radio announcements; and in-person educational sessions for communities (Lamunu, 2002; Muyembe-Tamfum et al., 1999). The WHO and various non-profits also generally provide well-trained volunteers to help set up Ebola clinics in isolated areas and to help train healthcare workers on the intricate protective procedures required for dealing with Ebola patients. All of these elements have been present in the WHO's response to the current Ebola outbreak. Shortly after confirming the outbreak in late March, the WHO sent surveillance teams to the affected countries, and soon thereafter sent teams to engage the community, help perform dignified burials, and help build and staff treatment centers (WHO, 2014e). Despite having some elements of previous responses, the WHO's initial response to the current outbreak has been subject to criticism over the perception that it was too small to adequately control the outbreak, despite the organization knowing that it was getting out of hand. While the WHO did respond to the outbreak as soon as it was alerted, it did not recognize that its wide geographical spread could potentially cause a serious epidemic, so it did not send as much personnel as would have been adequate. This meant that other organizations, like Médecins Sans Frontières (MSF), had to put in more work. MSF is a non-governmental humanitarian organization that is internationally renowned, but does not have the same level of power and resources as the WHO. MSF is usually good at providing medical personnel during outbreaks, but it relies on volunteers and was severely understaffed initially, resulting in patients being turned away from clinics that were at capacity (MSF, 2015). MSF repeatedly asked the WHO for additional help and warned them about the potential for

disaster, but these remarks were consistently written off and ignored. It was eventually revealed that the WHO was attempting to downplay the severity of the outbreak due to concerns raised by the governments of the affected countries. The leaders of these countries were apparently concerned that their economies and the annual Muslim pilgrimage to Mecca could be negatively affected if the WHO declared the epidemic an emergency, so the organization held off on doing so until two months after it had initially been considered (Cheng, 2015). By that point, the outbreak was out of control and was growing increasingly large. Had the WHO had a stronger initial response and declared an emergency sooner, it is likely that more international groups would have contributed sooner and the outbreak would not have spiraled out of control like it did. The WHO's lackluster response was clearly a contributor to the complexity of the ongoing outbreak.

Differences in Culture

Africa has an incredibly large number of diverse tribes, each with its own culture and customs, so it is entirely possible that cultural differences could be contributing to the complexity of the ongoing outbreak. While residents of large cities may not identify with a particular tribe, many of their customs are still practiced and the tribes themselves are still quite commonplace in rural areas. Specifically, differences in attitudes toward modern medicine and differences in burial practices will be examined since these cultural aspects are sometimes cited as factors that have influenced the courses of Ebola outbreaks.

In many poorly developed countries around the world there is a significant distrust of modern medicine. Because health systems in these countries may be substandard and many people may be too poor to utilize these systems, they often don't play a significant role in the day-to-day lives of people like they might in more developed countries. In addition, those in the isolated villages common in Sub-Saharan Africa may be hours away from the nearest hospital or clinic, so they may have to rely on other forms of healthcare. When trying to change people's practices involving something as essential as health, it is important that they experience the new system as often as possible in order to become more comfortable with it. Since this is not always possible for people in poorly developed countries, it can sometimes lead to distrust of modern medicine. This distrust is strengthened in cases of deadly infectious disease that are difficult to treat, like Ebola. When loved ones are dying off at a 70% rate despite the best efforts of doctors, people often feel as though modern medicine has failed them, so they shun outside help and turn to traditional healers. This phenomenon has been documented in most major outbreaks (Hewlett & Hewlett, 2007; Lamunu, 2002; Muyembe-Tamfum et al., 1999; WHO, 1978d). Although this hostility has been present in numerous outbreaks, it seems as though it may be a bit stronger in the areas affected by the current outbreak. In September 2014, a group of medical workers was killed by Guinean villagers over fears that they were bringing the virus with them (CNN, 2014). This increased hostility may be due to the fact that Ebola is new to the people of West Africa. Those who have experienced outbreaks before, like people in the DRC, have probably come to understand that while modern medicine cannot cure Ebola, it can help decrease the fatality rate more than traditional medicine would. People in countries lacking experience with Ebola, like Guinea and Liberia, on the other hand, still do not have enough

experience to understand this and are therefore more hostile towards modern interventions. In addition, the outbreak area is so large that social mobilization efforts by government and international organizations have not quickly been able to reach all affected areas. Whereas other outbreaks were ended in months due to the help of community engagement (WHO, 2001), there were still reports of hostility in Liberia almost six months after social mobilization initiatives began (WHO, 2014a, 2014c). This prolonged hostility has made it more difficult to isolate patients and to survey areas for new cases, potentially prolonging the outbreak in some areas. Thus, although some hostility has been observed in almost every major Ebola outbreak, it is possible that the somewhat increased and prolonged hostility encountered during the current outbreak has allowed it to grow and persist in some areas that could easily be helped.

Each African culture has its own set of procedures pertaining to the burial of the deceased, but many of them in Sub-Saharan Africa share characteristics that help contribute to the spread of Ebola. The vast majority of burial practices involve direct physical contact with the corpse by close family members, friends, or other community members. Most of this physical contact comes when these individuals wash the dead body to prepare it for burial. For example, Islam, the predominant religion in Guinea and Sierra Leone, calls for the body of the deceased to be washed by family members before burial (Tritton, 1938). The predominant religion of all of the previous outbreak locations is Christianity, a religion that does not call for washing during funerals. This may make it seem as though this practice has only contributed to the disease's spread during the current outbreak, but due to the mixing of Christianity and traditional African practices, this is not true. Although it is true that most people in Central Africa are Christian,

many of them, especially those in rural areas, combine their religious beliefs with traditional practices that do not directly conflict each other. Central Africa mostly consists of Bantu peoples, who traditionally bathe dead bodies before burying them, a practice that does not necessarily go against Christian teachings. Although the minutia of each individual ceremony may differ, the important thing is that every ceremony involves relatives washing the dead body. This practice is a major contributor to the spread of Ebola since it requires healthy individuals to come into direct contact with the body, and potentially the bodily fluids, of a still infectious individual. The WHO and other health organizations have consistently focused on stopping this practice during past outbreaks, although their approach has changed over the years. During the first few outbreaks, these organizations were not exactly sure what they were trying to combat, so they would simply take the dead bodies away without letting the family have any time with them, for fear of infection. This often led to the type of resentment toward healthcare workers previously described. Now that it is clear exactly how Ebola is transmitted, organizations focus on safely burying bodies, while being sensitive to cultural practices and the emotions of the family. Once these safe burial practices can be widely instituted, one very important mode of transmission can be eliminated. Unsafe burial practices certainly contributed to the spread of the disease during the current outbreak, but since there are no significant differences in the amount of physical contact during funerals conducted during any of the outbreaks, it is probably not one of the main factors that contributed to the immense size of the outbreak.

Differences in Physical Location

Table 3. Outbreak locations in relation to large cities

Year	Location	Approximate population at time of outbreak	Approximate distance to closest large city*
1976	Nzara, Sudan	20,000[10]	420 miles
1976	Yambuku, Zaire	35,000 in 15 mile radius[11]	260 miles
1995	Kikwit, Zaire	400,000[12]	N/A
2000-2001	Gulu, Uganda	120,000[13]	N/A
2002-2003	Kellé/Mbomo, RC	12,000 in 100 mile radius[14]	300 miles
2007	Luebo/Mweka, DRC	85,000 combined[15][16]	88 miles
2014-2015	Meliandou, Guinea	400[17]	6 miles

*A "large city" is defined as a city having a population ≥ 100,000 at the time of the outbreak.

Differences in the physical location of the beginning of an outbreak of an infectious disease can play a major role in whether or not the outbreak becomes an epidemic or remains an isolated batch of cases. Table 3 shows that there does not seem to be any distinct pattern in where the outbreaks initially occurred. Some began in well-populated cities, while others (including the current one) began in areas composed of relatively small villages. Since there is

[10] (Francis, 1978)
[11] (Breman, 1978)
[12] (CDC, 1995)
[13] (Uganda Bureau of Statistics, 2006)
[14] (Hewlett & Hewlett, 2007)
[15] (GeoNames, 2006c)
[16] (GeoNames, 2006a)
[17] (Faul, 2014)

no pattern that the current outbreak could have deviated from, it is clear that if there is some difference in location that could have cause the complexity of this outbreak, it does not have to do with population size or distance to the nearest large city. When comparing the outbreak locations on a map, one characteristic of the current outbreak's starting location does stand out: it is exceptionally close to multiple international borders and is within a reasonable distance of three international capitals. Meliandou is close to several roads that cross into Sierra Leone and Liberia, and it is also relatively close to a road that travels into Côte d'Ivoire. In addition, it is 250 miles or less from the capital cities of Guinea, Sierra Leone, and Liberia, all three of which currently have at least one million inhabitants and have significant, densely packed slum populations. It is not difficult to assume that infected travelers leaving the nearby city of Guéckédou were able to easily reach these large cities before developing symptoms. Once in densely populated cities like Freetown and Monrovia, an infected person would easily be able to start a chain reaction of infection. While some of the other outbreaks began in larger cities or very close to large cities, none of them have been in such close proximity to multiple international capitals. In addition, while some of them are technically close to very large cities, many of the outbreak locations are actually relatively isolated, with poor access to the cities close by. Because of this it seems as though the spread of illness was often limited only to the areas immediately surrounding each city. Even in the cases where the illness did spread to a very large city, it never managed to gain a foothold like it has done in the current outbreak, potentially because authorities in the larger cities had been alerted to the fact that there was an outbreak occurring close by. In any case, it is clear that Meliandou's unique location has been a major contributor to the complexity of this outbreak.

Conclusion

After examining the evidence, it can be determined that there is not simply one factor that has led to the current Ebola outbreak being so complex. Instead, it seems as though the combination of lack of awareness, poor public health spending, a meager international response, and a very centralized location is the cause. Ebola had never been seen in West Africa before this outbreak, so doctors and public health officials had no idea what they were actually dealing with at first. This allowed the outbreak to spread to and throughout numerous large cities while remaining undetected for three months. The lack of awareness was supplemented by the fact that the initial outbreak location, Meliandou, Guinea, is very close to several international borders and has easy access to roads that lead to the capitals of three countries. However, these two factors alone probably would have caused a less severe outbreak had it occurred in a more developed country. The affected countries all spend less than half the amount of money on pubic health that most developed countries do, leading to a shortage of doctors and beds in hospitals. The poor public health systems could have been negated by a good international response, but the main international public health organization, the WHO, was initially unwilling to recognize the seriousness of the outbreak due to political concerns. All of these factors worked together to create the perfect set of circumstances for an enormous outbreak to occur. An interesting observation is that the mortality rate of the current outbreak is significantly lower than previous outbreaks involving the Zaire strain. Further research should be done to conclude whether this phenomenon is related to genetic changes or other variables, including the ones discussed in this paper.

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