# Historical Analysis of the Ebola Virus: Prospective Implications for Primary Care Nursing Today

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## ABSTRACT

Ebola continues to attract worldwide attention as a highly lethal virus of unknown origin that leaves victims bleeding to death and has no known vaccine or cure. The purpose of this historical research was to review and analyze the primary and secondary sources available on Ebola for use by primary care nurses in the event of future outbreaks. A rich resource of history has been well documented by some of the original physicians, virologists, and members of international teams, but nothing was found to be documented by nurses during these outbreaks. Multiple themes emerged including the origins of the viral strains of Ebola, transmission factors, epidemiology, virology, nonhuman and genetic research, treatment, and clinical implications. This research will provide primary care nurses with historical information about Ebola to help in future treatment options and algorithm development.

**Key words:** filovirus, viral hemorrhagic fever, Africa, historical nursing research

The Ebola virus has recently attracted worldwide attention as a result of the outbreaks and human fatalities in Africa. Few viruses are more notorious or lethal. Ebola is a highly virulent filovirus that produces a hemorrhagic fever and disease process, causing victims to bleed to death. While all hemorrhagic fevers pose a threat, Ebola is a level 4 virus, for which containment remains the greatest challenge because these viruses produce the most lethal illnesses and, for the most part, do not respond to treatment (McCormick, Fisher-Hoch, & Horvitz, 1996). There is very limited knowledge about this highly pathogenic virus that is capable of epidemic transmission in humans, and little is known about Ebola's viral family, filoviridae (Peters, et al., 1994).

There are four known viral strains of Ebola. The Zairian strain is considered the most deadly form, as it causes a high fever and bleeding from every orifice (Seppa, 1998) and historically has the highest fatality rate in humans. The source of Ebola has never been found, and this is one of the greatest concerns for the scientific and medical communities. The origin of the index cases pinpointed to charcoal pits or cotton factory rooms in Africa, but the host vector has never been located.

The purpose of this study was to review and chronicle published materials for nursing that document the events surrounding the various Ebola outbreaks as a result of the human and nonhuman contacts with the virus. Reports from healthcare personnel who have treated patients in an outbreak or who have had contact with the virus through research were all examined.

## Methods

Limited historical knowledge about Ebola has been documented in nursing research, yet the threat of this virulent disease remains throughout the world today. A comprehensive understanding of the history of Ebola is vital when considering the basis for nursing practice and further research in the treatment and transmission of this deadly virus. Historical analysis was the chosen method, as it can answer questions concerning past events as to the causes, effects, and trends that may shed light on current practice (Polit & Hungler, 1991). In historical research, the events of the past are uncovered and relate to the present and future (Nieswiadomy, 1993). The hope is that more historical research will focus on significant events and

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developments in nursing practice, rather than only on nurse leaders (Nieswiadomy, 1993).

In historical research, each piece of information is examined for evidence and evaluated for accuracy and meaning, as Kruman (1985) has recommended. In this study, evaluating the information for accuracy, meaning, and chronology remained the greatest challenge. As recommended by Kruman (1985), both primary and secondary sources were used. When episodic information from two primary sources conflicted, an interpretive determination was made about what truly happened, as Burns and Grove (1997) have recommended. Journal articles from physicians and virologists on site and other published material were collected, reviewed, and updated over a 2-year period.

Historical evidence was examined for accuracy, genuineness, and authenticity. Unlike a great deal of historical research on individuals in nursing, genuineness and authenticity were of less concern here because most of these sources were from published peer review journals. Most experienced researchers spend less time deciding on the authenticity of a document than on its meaning; the historian critically evaluates for meaning of a source (Kruman, 1985). The emphasis of this research was on the interpretation and meaning of the sources and the accuracy of the timelines surrounding the numerous details of the many outbreaks.

The goal was to review and synthesize the information that has been published about Ebola to date, with the emphasis, where possible, on primary source materials. Both types of sources yielded findings about the actual history of Ebola. A rich history was discovered to be well documented by some of the original scientists, physicians, virologists, and members of the international teams that were on the scene during the initial outbreaks of Ebola. Unfortunately, the literature by nurses present during the outbreaks is nonexistent.

The hope was that this research would serve as the groundwork for further study in the eventual development of international nursing protocol and algorithm guidelines for the nursing interventions, treatment, and containment of the Ebola virus during an outbreak. The historical information should heighten our awareness about this lethal killer, which threatens to emerge again, anywhere on the globe.

## Outbreaks and Strains

Ebola first emerged near the Ebola River in 1976 in what was Zaire and is now the Congo (Seppa, 1998). Five countries in East, South, Central, and West Africa have been affected by this virus. There have been 851 cases and 595 deaths, with the majority in two countries, Sudan and Zaire (Congo) (Tukei, 1996). There have been five outbreaks in Zaire and Sudan (1976), Sudan (1979), Zaire (1995), Ivory Coast (1995), and Gabon (1996). In the United States, there have been two nonhuman outbreaks in primates in Alice, TX, and Reston, VA (1989). The five human outbreaks and two primate outbreaks have been tracked down to one of the viral strains. There have been four distinct Ebola viruses identified since the initial outbreak of Ebola in Africa in 1976; they are Zaire, Sudan, Côte d'Ivoire, and Reston (Georges-Courbot, et al., 1997).

For humans, the Zaire strain of Ebola remains the most lethal, with a mortality rate as high as 88%. Another strain, Reston Ebola, has been found to be transmissible by aerosol between monkeys, and there is great concern that the more lethal forms of Ebola could mutate to an aerosol form as well (Tukei, 1996). Transmission by monkeys has been linked to outbreaks in the Tai Forest in the Ivory Coast and in Gabon. The first and still the most lethal strain of Ebola is the Zaire strain, discovered in Zaire in 1976; it is lethal and swift, and it mysteriously manages to completely disappear between outbreaks (Fox, 1998).

### Yambuku, Zaire, 1976: Zaire Strain

It has been over 22 years since the first outbreak of Ebola was documented in Yambuku, Zaire, in 1976. Yambuku was the site of a mission run by Flemish nuns that contained a hospital and a school in a largely agricultural community (Panwalker, 1997). During the initial outbreak of Ebola, the mission found itself without the means to handle an epidemic (Panwalker, 1997), and, initially, the international community was slow to respond. The hemorrhagic fever spread rapidly, generating horror and panic and sparing few lives. Among the 318 people who died were nurses and Belgian missionary nuns who had cared for the sick (Peters & Olshaker, 1997).

The first clinical reports coming out of the region were written by the Chief Medical Officer, Dr. Ngoi Mushola, who visited the area in September 1976, after the index case and 13 others had died (Sureau, 1989). After witnessing 13 more deaths from Ebola, he observed the following:

> The disease was characterized by a high fever of ~39°C, with hemorrhagic manifestations such as vomiting of digested blood but sometimes red blood hematemesis and diarrhea with blood-striated mucus at the beginning and later with pure red blood and epistaxis. (Sureau, 1989, p. S790)

The second clinical reports from Yambuku, by Drs. Muyembe and Omombo, were also written in September. They mentioned other clinical symptoms including "hemorrhagic manifestations such as conjunctival injection, hematemesis, and melena" (Sureau, 1989, p. S90).

In early October, Drs. Ruppol, Raffier, and Krubwa stated that

> All patients that died of "Yambuku disease" had presented with abrupt onset of high fever, headache, myalgia, and arthralgia, which was followed after 3–4 days by hemorrhagic complications such as hematemesis, diarrhea with fresh red blood and later melena, sometimes hematuria, and in some cases epistaxis and petechia. (Sureau, 1989, p. S790).

Dr. Sureau arrived in Yambuku in mid-October and reported additional findings of anorexia, abdominal pain, sore throat, expressionless faces, and "profound prostration" (Sureau, 1989, p. S90). He also reported that after the fifth day of the acute phase, a rash would appear on the trunk. This would herald the beginning of the hemorrhagic symptoms, which included "hemorrhagic conjunctivitis, bleeding ulcerations in the mouth and on the lips, gingival bleeding, hematemesis, melena, epistaxis, ear bleeding, hematuria, and postpartum hemorrhages" (Sureau, 1989, p. S790). All hemorrhagic cases had a fatal outcome within about a week (Sureau, 1989). The 34 nonfatal infections were in individuals who were retrospectively found to have antibodies to the Ebola virus (Sureau, 1989).

An American physician, Dr. William Close, was also present during the epidemic in Yambuku. According to Close (1995), at the time of these outbreaks, supplies of intravenous fluids were limited, and basic equipment and medicine were nonexistent. Despite the presence of well-trained Zairian doctors and nurses, few basic supplies were available in these government hospitals (Close, 1995). Meanwhile, a second outbreak was occurring in Sudan.

### Nzara and Maridi, Sudan, 1976: Sudan Strain

The 1976 outbreak of Ebola Sudan occurred in southern Sudan, in Nzara and Maridi (McCormick, et al., 1996). From 1977 to 1989, additional, sporadic cases were reported, such as in Nzara in 1979 (Meslin, 1997). As in Yambuku, transmission of the Sudan strain was thought to come from close contact with infected blood, reuse of contaminated needles, and improper nursing technique (McCormick, et al., 1996); the Sudan outbreaks were thought to originate from the Nzara cotton factory. Ebola's next emergence would be in the primate population.

### Reston, VA, 1989: Reston Strain

In 1989, a new Ebola-related virus was isolated from macaque monkeys imported from the Philippines. Held in a primate facility in Reston, VA, they developed a deadly hemorrhagic fever (Meslin, 1997). The Reston strain would appear again in macaques imported from the Philippines into Italy (1992) and Alice, TX (1990, 1996) (Meslin, 1997). In the Texas primate facility, two monkeys were found to be the carriers for Reston (Dowell, 1996).

The Reston outbreak offered scientists the rare opportunity to study the monkey-to-monkey transmission of the virus (Ryan, 1997); it also provided the sobering realization that Ebola was now emerging from the Asian rain forests. The monkeys in this outbreak developed a respiratory pattern that included severe coughing, pneumonia, and copious secretions that were found to be loaded with Ebola virus (Ryan, 1997). Under the electron microscope, the virus was seen in the air sacks and alveolar lining, which confirmed the upper respiratory infection complicated by pneumonia (Ryan, 1997). It was later confirmed that the Reston virus had been spreading from room to room by aerosolization.

### Makokou, Gabon, 1994 and January and October 1996: Zaire Strain

Makokou, Gabon, was the site of three independent outbreaks of the Ebola virus in less that 2 years (Georges-Courbot, et al., 1997). In 1994, dead chimpanzees and gorillas were reported in the forest by the Minkouka area inhabitants (Georges-Courbot et al., 1997). The outbreaks of 1996 struck human populations. In the first outbreak, most patients had come into contact with the virus while butchering chimpanzees (Meslin, 1997). The index case during the third outbreak was identified as a hunter living in a forest camp near where a virus-infected chimpanzee was found (Georges-Courbot, et al., 1997). The Zaire strain found in Gabon was transmitted in small numbers through several generations of humans (Peters, 1997). One South African nurse reportedly died as a result of exposure to an Ebola patient who had arrived from Gabon (Peters, 1997).

### Ivory Coast, 1994: Ivory Coast Strain

In 1994, a Swiss investigator became infected while doing a postmortem on a chimpanzee from the Tai Forest in the Ivory Coast (Côte d'Ivoire), where there had been numerous chimpanzee deaths reported (Meslin, 1997). The new viral strain was called Ebola Ivory Coast. It was lethal to the chimpanzees and possibly to humans (Le Guenno, et al., 1995), as infected patients developed severe symptoms but survived. The most astonishing discovery about Ebola Ivory Coast was that the virus had remained alive in a blood sample despite poor storage and two cycles of freezing and thawing during transport to the laboratory (Ryan, 1997). This was a significant indicator of how the Ebola virus could survive conditions of extreme adversity (Ryan, 1997). The good news was that in the Ivory Coast outbreak, an epidemic was avoided be-

cause of the progress that had been made in good nursing techniques with the use of disposable injection devices (Le Guenno, et al., 1995).

### Kikwit, Zaire, 1995: Zaire Strain

The index case of the Kikwit outbreak was a middle-aged male charcoal worker who contracted the disease, infected his household (Ryan, 1997), and died.

During the Kikwit epidemic, patients presented with fever, diarrhea, severe weakness, bleeding, and hiccups (Butler, Kilmarz, Jernigan, & Ostroff, 1996). The Kikwit outbreak generated a strong international response from the onset, because by 1995, it was known that containment and control of the disease were critical. The population of Kikwit was subsequently educated about transmission modes and the necessity of bringing all infected persons to the hospital in Kikwit (Butler, et al., 1996). The hospital was restaffed; gloves, gowns, and masks were provided; and all volunteers providing transport for infected patients were given protective materials and training (Butler, et al., 1996). Seminars were conducted to educate healthcare workers on barrier nursing techniques, disease reporting, and patient case identification (Butler, et al., 1996).

Although Kikwit and Yambuku are hundreds of miles apart, the pattern of the 1995 epidemic resembled Yambuku (Ryan, 1997). Hospital workers denied spreading the virus by contaminated syringes, but failure to adopt simple barrier nursing procedures was implicated in the 44% death rate of the hospital workers (Ryan, 1997).

During the Kikwit outbreak, an international scientific and technical committee was set up in Kikwit to investigate and control the epidemic (Muyembe & Kipasa, 1995). The team's goal was to understand the disease processes and identify the viral reservoir if possible. The team was also actively involved in patient management, epidemiologic studies, isolation of new cases, and improving the cleanliness of the health facilities (Muyembe & Kipasa, 1995). The members of the international team from the Special Pathogens Branch of the Centers for Disease Control and Prevention (CDC) from Atlanta, GA, included A. Sanchez, P. E. Rollin, T. G. Ksiazek, and C. J. Peters (Muyembe & Kipasa, 1995).

Rollin was on the first CDC team to arrive in Kikwit. With colleagues, he cleaned floors, treated patients, and taught prevention, often working without water, electricity, or clean needles (Winik, 1998). As Dowell (1996) mentioned, one of the great tragedies of the Kikwit outbreak was that people caring for their sick relatives were putting themselves at risk, which only contributed to the rapid transmission of the virus.

## Transmission

One of the great concerns with the Ebola virus is the issue of transmissibility. According to Peters (1997), this has not been studied carefully, although we do know that Ebola virus can be transmitted between animals in the laboratory, and some formal studies have shown that in animals there is infection by aerosol. Most testing, however, has occurred not in the field but in a biosecurity level 4 facility (Peters, 1997). It has been speculated that some patients had had contact with infected bats or rodents in Sudan and meat from wild monkeys or antelopes in Zaire (Meslin, 1997). The definitive source, however, remains unknown (Meslin, 1997).

There is no evidence of any interhuman transmission of Ebola virus by aerosol in Zaire (Peters, 1997). The implications for aerosol transmission would be important for determining the type of respiratory precautions needed (Peters, 1997). There would be further concern that the virus could also cross the species barrier and be readily transmitted between humans (Peters, 1997).

Of all the strains, Ebola Zaire remains the most lethal and should be followed for potential aerosolization. Researchers have shown that fatal aerosol transmission is possible in a laboratory environment in nonhuman primates (Johnson, Jaax, White, & Jahrling, 1995). The laboratory environment used for these experiments had conditions of lower temperature and humidity than are found in the regions of Africa where Ebola has appeared (Johnson, et al., 1995). If the filovirus were to become more stable at the lower temperatures and humidity levels that favor other types of hemorrhagic viruses, this could pose a major problem.

Aerosol exposure remains a potential threat for humans, as the Ebola Zaire strain was found to aerosolize in the laboratory setting with monkeys. Healthcare workers need to practice infectious disease technique that includes all the barrier protection and respiratory precautions that "curtail aerosol-generating procedures" (Johnson, et al., 1995, p. 234). Researchers have shown that a deadly combination of aerosolized Zaire was possible in the laboratory setting, but it is not known if this could occur in nature.

## Epidemiology

The great mystery remains as to where the original source of the monkey and human infections lies and how the virus is introduced into animal populations (Joklik, Willett, Amos, & Wilfret, 1992). In humans, there are several explanations as to why infection from animals to humans is actually rare. One is that transmission occurs only in certain instances, such as when hospitals become the amplifier (Joklik, et al.,

1992). Another is that the primary infective transmission from the natural reservoir to humans is simply a rare occurrence (Joklik, et al., 1992).

The question of where Ebola "hides" between outbreaks still remains a mystery (Rodier, 1997). It is not known where Ebola goes between epidemics, and in order to maintain disease surveillance and control these unanswered questions are important (Rodier, 1997). The natural cycle of the Ebola virus is not known, nor is the reservoir (Meslin, Stohr, & Formenty, 1997). Despite the fact that monkeys have been tied to the virus, it is not believed they are the primary host because the mortality is so high that they could not sustain themselves or the virus for long periods of time (Meslin, et al., 1997).

It has been hypothesized that Ebola is a plant virus (Le Guenno, et al., 1995). A charcoal worker from the rain forest was one of the first index cases. The rain forest may still hold many clues about Ebola. Ebola may, literally, be somewhere in the earth. Yet, despite the many samples taken from the Ivory Coast, the source of the virus has never been found.

## Virology

Ebola, along with the deadly Marburg virus, is a member of the filoviridae family (Peters, 1997), named for the filamentous form of the viral particles, which can be seen with an electron microscope. The virus has been described as having four distinct subtypes and the unusual ability to conserve its genetic makeup, whereas, typically, RNA viruses are highly mutable (Peters, 1997). Volchkov, et al. (1997) confirmed this in explaining that the subtypes of the Zaire virus are remarkably similar, despite different areas of outbreak, and have shown remarkable genetic conservation for an RNA virus over 20 years.

The Kikwit outbreak provided the first opportunity to study a small number of patients who were survivors, made antibodies, and had a detectable immune response (Peters, 1997). This was an important step in understanding the virology of Ebola. In Kikwit, the viral antigen presented in pulmonary capillaries, alveolar macrophages, and pneumocytes, and liver involvement was characteristic (Peters, 1997). Infectious virus was also found in the skin (Peters, 1997). Infection was taking place transdermally during the preparation of family members' bodies for mourning (Peters, 1997).

Ebola hemorrhagic fever is not an immunopathologic disease, but a negative-strand RNA virus. There is no vaccine available, and despite the best care, viral involvement of nearly every organ of the body ensues (Peters, 1997). How the virus works in nature is best witnessed during an outbreak, but research studies in the laboratory setting offer valuable opportunities for study. It is known, for instance, from laboratory studies that the virus works by producing complete platelet and endothelial cell dysfunction; despite having plenty of circulating platelets available, the platelets lose their ability to aggregate properly (Joklik, et al., 1992). Further nonhuman studies need to be examined to understand how Ebola is manifesting itself in the laboratory setting and to discover future possibilities in the area of vaccine development.

## Nonhuman and Genetic Studies

There have been several nonhuman primate studies on Ebola, including one on infection of cynomolgus macaques with the Reston strain; another on infection of rhesus monkeys with the Zaire strain; which proved that aerosol transmission between monkeys was possible in the laboratory setting; and one on infection of African green monkeys with the Zaire strain. Important previous findings that were supported in the green monkey experiment included viral presence in many cells and organs and high titers (Davis, et al., 1997), which described reaction to the presence of the virus. The Ebola Zaire virus was shown to be targeting not only the mononuclear phagocyte system and endothelial cells, but also the fibroblastic reticular cells (Davis, et al., 1997). The fibroblastic reticulum is a vast network that links much of the lymphatic system and vasculature of lymphoid tissues. It plays an important role in immune response efficiency (Davis, et al., 1997). The Ebola virus is thought to adversely affect the whole interconnected system and therefore the immune response of the antigen-presenting cells of the mononuclear phagocyte system (Davis, et al., 1997).

Research to mitigate or prevent the effects of Ebola includes the study of polymers and vaccine trials. Polymers, which work by attaching to red blood cells, can be used to reduce the level of disease-causing organisms in the body by 1 million times (Manning, 1997). In vaccine trials with nonhuman subjects, researchers at the University of Michigan Medical Center have been partially successful in vaccinating guinea pigs to lethal Ebola virus (McCarthy, 1998).

The World Health Organization (WHO) has had teams of scientists from around the globe working in the Tai Forest to discover Ebola's transmission mechanisms in nature to identify the natural reservoir of the virus (Meslin, et al., 1997), which may one day lead to prevention of an outbreak.

Other researchers have made progress in genetically analyzing the Ebola virus. Ramanathan and Taylor (1997) found that Ebola Zaire, the most lethal form of the virus, places "unprecedented selenium demand on the host" (p.94), thus contributing to the hemorrhagic symptoms because of "severe lipid peroxida-

tion and cell membrane destruction" (Ramanathan & Taylor, 1997, p. 94). The authors concluded that the hemorrhagic symptoms of Ebola were in fact a consequence of clot formation and the coagulation of disseminated intravascular coagulation.

It has been shown in both biochemical and *in vivo* studies that there is a link between selenium deficiency or selenium depletion, probably due to a proclotting mechanism that can lead to hemorrhage (Ramanathan & Taylor, 1997). It is thought that selenium could also be involved in the manifestations in hemorrhagic viral diseases (Ramanathan & Taylor, 1997). This is supported by the work of Hou and coworkers, who treated an outbreak of viral hemorrhagic fever (VHF) with high-dose sodium selenite, resulting in dramatic reductions in mortality during an Asian outbreak (Ramanathan & Taylor, 1997).

The theoretical findings of these genetic researchers suggest that there may be some type of viral requirement in Ebola for selenium and that this also contributes to the viral pathology itself when there are conditions of depletion of selenium in the human and animal populations (Ramanthan & Taylor, 1997). Selenium has a well-documented role in the regulation of blood clotting; a selenium deficiency, on the other hand, can have a proclotting, or thrombotic, effect (Ramanathan & Taylor, 1997). As Lavander and Beck have proposed (Ramanathan & Taylor, 1997), certain geographic areas may be prone to lower selenium levels and therefore to producing new virulent diseases.

It is possible that treatment with selenium helps to counter a virally induced selenium depletion (Ramanathan & Taylor, 1997), and it is reasonable to believe that selenium plays a significant role with Ebola virus. Ramanathan and Taylor have stated that "our analysis of Ebola suggests the presence of UGA-rich PPCRs and the potential SECIS elements may indicate depletion of host Se by the programmed synthesis of specific selenoproteins" (1997, p. 103). It may also be possible to detect Ebola virons in early infections, before cellular stores of selenium are depleted (Ramanthan & Taylor, 1997). There may be an antioxidant module that accompanies the Ebola viron and is released as a soluble factor in that cell and that defends the virus against the oxidative attack by the immune system (Ramanathan & Taylor, 1997). In the severe infection processes of Ebola and other hemorrhagic fevers, there may be such a severe selenium depletion, resulting in cell damage and thrombosis, that the selenium status should be checked in these patients (Ramanthan & Taylor, 1997).

In comparing the lethality of the Zaire and Reston strains, the issue of selenium deficiency and viral codon differences has helped to answer this question. Reston is more lethal to monkeys and less lethal to humans. Although the two strains of Ebola had previously been thought to be connected very closely genetically (Ramanathan & Taylor, 1997), in fact, there is a major difference between the two strains. In the Reston strain, there was no potential expression for the selenoprotein gene (Ramanathan & Taylor, 1997). In the Zaire strain, the selenium-rich environment favored selenoprotein expression, which in turn contributed to a high human mortality rate.

Several thoughts emerge from this research, not the least of these being to further explore the work that Chinese researchers have done with selenium trials in treating VHF that might be applied to treating the early stages of Ebola Zaire. Since Ebola Zaire needs a selenium-rich environment, there could be a clue here that the host, be it plant or animal species, in its natural habitat requires a selenium-rich environment. This could help lead us to the reservoir of Ebola Zaire. It could be more difficult for Ebola Zaire to take hold within a selenium-healthy population and, in theory, there would be fewer fatalities during such outbreaks. Many areas of the world have selenium-deficient soil that produces crop deficiencies in selenium, including areas of Africa.

## Treatment

The natural history of this virus is still virtually unknown (Peters, et al., 1994). Ebola's high pathogenicity for humans, combined with the potential for aerosol infections and high probability of possible reoccurrence (Peters, et al., 1994), is enough to be of considerable concern for nursing. There is no specific therapy such as antiviral drugs, interferon, or convalescent plasma (Peters, et al., 1994). Protease inhibitors may be a consideration for treatment (N. Jaax, personal communication, May 1, 1997). Filovirus infections are not very sensitive to antiviral efforts of interferon, nor are they neutralized by convalescent plasma or inhibited by ribavirin (Peters, 1997). Unfortunately, there is still no therapeutic modality that can be offered to a laboratory worker or patient exposed to the Ebola virus.

International infectious disease teams are still searching for the vector. During each new outbreak, teams from the U.S. Army Medical Research Institute of Infectious Diseases, the CDC, and the WHO work together to track down the latest index case in hopes of gaining new clues as to the origin of the virus and the host vector. These clues offer the greatest hope for the treatment and continued vaccine development.

## Clinical Implications

It is essential that nurses become fully aware of any guidelines, protocols, and barrier nursing techniques that have been employed during recent outbreaks.

The CDC has published recommendations for VHF fully outlining proper barrier precautions and waste disposal. The CDC also maintains an Ebola hotline. It is important that epidemic emergency preparedness plans be available for nursing personnel around the world. Nurses should be educated about how to handle a potential tropical disease outbreak. There is concern by those who have worked closely with Ebola (Johnson, 1993) that the medical and scientific community have historically been reactive and not proactive. A retrospective history is needed so that prospective education and prevention can begin.

As outlined in *Healthy People 2000* (U.S. Department of Health and Human Services, 1992), healthcare providers need to work to increase the span of healthy life for Americans and to achieve access to preventive services for all Americans. Internationally, nursing plays a vital role in the future containment of the spread of highly infectious diseases such as Ebola.

In the earliest outbreaks of Ebola, it was later found that the spread of disease was due to the amplified effect of the reuse of syringes by missionary nurses (Garrett, 1994). The nurses in the mission hospital in the Yambuku outbreak in 1976 used five syringes on the average of 300 to 600 patients a day (Garrett, 1994), which helped to spread the virus. Again in 1979, in Sudan, Ebola flared because of the reuse of nonsterile syringes in local medical facilities around the Nzara cotton factory (Garrett, 1994). Outbreaks of a host of diseases have been implicated in hospital and clinic settings, where invasive devices or medical equipment have served as the amplifier (Garrett, 1994) and the potential for nosocomial infection was great.

Person-to-person and animal-to-animal transmission is a very serious concern, and those who care for humans infected with the virus certainly are at risk from nosocomial infection including the handling of contaminated materials, contact with bodily secretions, and exposure during burial preparations (Joklik, et al., 1992). Observing the most basic tenets of nursing practice in an outbreak is crucial and must include barrier methods, universal precautions, and aggressive hand washing. Assessment for potential disease exposure must be part of the history taking and physical assessments. It is critical that nurses receive education about hemorrhagic tropical diseases. The responsibility for disease surveillance ultimately must lie with individual clinicians in the world community.

Advanced practice nurses also play a crucial role and can implement guidelines and algorithms for potential use during epidemics. Nurse practitioners (NPs) are in a prime position to implement change not only in the healthcare delivery system, but also to influence healthcare policy, reimbursement, and the redefining of priorities from illness to wellness and from medical care to health care (Hawkins & Thibodeau, 1996). Just as NPs have been called the mavericks and risk takers in the nursing profession (Hawkins & Thibodeau, 1996), they must take responsibility for being educated about viral killers such as Ebola.

In the United States, there has been no official surveillance system or nationally organized response system to deal specifically with a major viral emergency in this country or the ability to rapidly test specimens, advise clinicians, and state departments of potential threats (Legters, Brink, & Takafuji, 1993). Hospitals have been ill equipped to handle any highly contagious lethal microbes (Legters, et al., 1993) and have been found to lack even basic biocontainment equipment. During an epidemic, the U.S. Army has deployable field hospitals that can be used to isolate patients with highly communicable diseases, but there probably would not be enough military clinical expertise to staff civilian hospitals during an epidemic (Legters, et al., 1993).

The WHO, however, has formed a Division of Emerging and Other Communicable Diseases Surveillance and Control (EMC) to help strengthen national disease surveillance programs and develop a worldwide detection system that would have rapid epidemic response (Heyman, 1997). The success of the EMC is dependant on the willingness of nations to communicate information nationally and internationally (Heyman, 1997). The EMC provides, through WHO, technical assistance, training, communicable disease surveillance, and public laboratory support with collaborating WHO centers linked throughout the world via the World Wide Web (Heyman, 1997). This communication will help in the development of early warning systems and in monitoring infectious disease outbreaks around the world (Heyman, 1997).

Monitoring the public health is the CDC's Epidemic Intelligence Service, which has specially trained epidemiologists on alert for the threat of biological warfare (Steinbruner, 1998). These are the famous disease detectives popularized by the media that contain disease outbreaks around the globe. As the worldwide threat of infectious disease continues to increase (Morris, 1997), nurses must be prepared along with physicians and other healthcare professionals, to handle tomorrow's epidemics. The public health infrastructure must maintain a state of readiness and be able to respond quickly and to mobilize to new areas of outbreaks during epidemics (Butler, et al., 1996).

## Conclusions

Recent historical analysis of the literature has revealed important information on changing the body of research for contending with future Ebola outbreaks. Areas of particular interest concern treatment

and genetic research, especially the Chinese use of selenium to treat other VHFs. The greatest chance for patients at risk for Ebola may lie in the ability of nursing to prepare itself for times of epidemic crisis. Clinicians must be knowledgeable about the historical presenting symptomatology and patterns of disease so that swift and accurate differential diagnosis can be made and precautions implemented when Ebola returns.

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