Viral Hemorrhagic Fever Preparedness

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Introduction

The 2014–2016 outbreak of Ebola virus disease (EVD) in West Africa marked the 25th such occurrence but was noteworthy in its massive scope, causing more human morbidity and mortality than the previous 24 recorded outbreaks combined. As of April 2016, there were 28,652 cases resulting in at least 11,325 deaths, nearly all in the three nations of Guinea, Liberia, and Sierra Leone [1]. Moreover, the 2014–2016 outbreak was the first in which patients, albeit few in number, were afforded sophisticated intensive care in the United States and in Europe. This "high-level containment care" (HLCC) was provided in specially designed purpose-built biocontainment units (BCUs). In this chapter, we explore the history and evolution of biocontainment, discuss its unique engineering and infection control modalities, and offer recommendations for the clinical and operational management of Ebola and other viral hemorrhagic fevers (VHFs).

History of Biocontainment

The modern concept of biocontainment had its birth in 1969 with the convergence of four separate events. In May of that year, Michael Crichton published *The Andromeda Strain*, and, while the work was clearly fictional, it debuted amidst a series of discussions leading up to President Nixon's decision in November of that year to abandon the US offensive biological weapons program. Nixon's decision was a prelude to ratification of the 1972 Biological Weapons Convention and to the US ratification, in 1975, of the Geneva Protocols. At the time, Nixon stated that "the United States has decided to destroy its entire stockpile of biological agents and confine its future biological research program to defensive measures." Implicit in that decision was a shift in the focus of US efforts to defensive and medical countermeasure development that would include an emphasis on the management of patients potentially infected with highly hazardous human pathogens. This medical defense program would fall largely upon the newly created US Army Medical Research Institute of Infectious Diseases (USAMRIID), an entity which would inherit its defensive mission from the old Army Biological Laboratory (ABL).

The year 1969 also witnessed the discovery of Lassa virus by Dr. Jordi Casals-Ariet at Yale University [2]. While attempting to characterize the new virus, Dr. Casals contracted Lassa fever himself and fell critically ill but survived following the administration of convalescent serum from one of his patients. Unfortunately, one of his technicians, Juan Roman, succumbed to the disease while conducting laboratory studies, causing Dr. Casals to move his research to a new maximum-security laboratory at the Communicable Disease Center in Atlanta (now

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the Centers for Disease Control and Prevention) and ushering in a new era of laboratory safety.

Finally, 1969 saw man's first journey to the moon, aboard Apollo 11. In order to guard against the remote possibility that extraterrestrial pathogens might inadvertently accompany the returning astronauts, a new facility, the Lunar Receiving Laboratory (LRL), was constructed, in consultation with ABL experts, at the Johnson Manned Spaceflight Center in Houston. The facility would receive spacecraft, equipment, and lunar samples from Apollo 11 and from future Apollo missions. Moreover, it would serve as a quarantine facility for the returning astronauts from the Apollo 11, 12, and 14 missions.

Included among the assets of the USAMRIID facility was a novel two-bed high-level containment care unit [3]. This unit, often referred to as "the Slammer," presumably owing to the sound produced by the closure of its heavy steel airlock doors, opened in 1971 and included engineering controls analogous to those employed in Biosafety Level 4 (BSL-4) laboratories. The facility was designed to treat infected patients but also to provide confidence and a sense of security to scientists and to the community of Frederick, Maryland, in which it was located.

During the period 1972–1985, 20 individuals were admitted to the Slammer following laboratory or field exposure to a variety of BSL-4 pathogens [4]. A 21st patient (exposed to Ebola in the laboratory) was admitted in 2004 [5]. Of note, none of the 21 patients developed clinical evidence of infection. The Slammer was decommissioned in 2012; a new USAMRIID building, slated to open in 2017, will not house a containment care unit.

The intentional dissemination of anthrax via contaminated mail in October 2001, occurring just weeks after the World Trade Center assault and, ironically, attributed to a troubled USAMRIID scientist, convinced some civilian experts to move in the opposite direction and propose the creation of academic medical center-based HLCC facilities. Outbreaks of severe acute respiratory syndrome (SARS) and monkeypox in the spring of 2003 added impetus to these construction projects, SARS because of its high mortality and apparent transmission via droplet nuclei and monkeypox owing to a resistance among fearful healthcare providers to treat victims of the disease [6].

During 2004–2005, a two-bed facility at Emory University in Atlanta and a ten-bed facility at the University of Nebraska Medical Center in Omaha opened; the facilities employed some (but not all) of the engineering controls contained within the USAMRIID facility. In 2005, leaders from these facilities, as well as USAMRIID and the Centers for Disease Control and Prevention (CDC), published consensus guidelines for the employment of HLCC units [7].

In that same year, the National Institute of Allergy and Infectious Diseases (NIAID) contracted with Saint Patrick Hospital in Missoula MT to construct the first HLCC unit housed outside of a large university-based medical center in order to care for scientists exposed to BSL-3 and BSL-4 pathogens at the NIAID's Rocky Mountain Laboratories in nearby Hamilton [8]. As of this writing, no patients have been cared for in this facility. In 2010, the Special Clinical Studies Unit at the National Institutes of Health adapted its seven-bed clinical research unit in order to provide HLCC. This facility, along with those at Emory and Nebraska, cared for 9 of the 11 victims of the 2014–2016 West African Ebola outbreak managed in the United States. One patient was managed under HLCC conditions at Bellevue Hospital in New York, and one patient was managed at Dallas Presbyterian Hospital.

Germany possesses seven HLCC facilities, four of which cared for EVD victims during the 2014–2016 West African outbreak. Some of these units have experience in treating patients infected with Marburg and Lassa viruses as well. Biocontainment units in Britain, France, Spain, the Netherlands, Norway, Switzerland, and Italy also successfully cared for expatriate patients during the recent EVD outbreak, and European nations have been pioneers in the development of HLCC doctrine [9, 10]. Finally, China, at the height of the SARS outbreak in 2003, constructed a 1000-bed infectious disease treatment facility equipped with engineering controls designed to ameliorate the risk of airborne transmission of the SARS coronavirus [11]. Other nations in the region, such as Singapore and South Korea, are constructing HLCC facilities as well.

Background: Viral Hemorrhagic Fever (VHF)

The viral hemorrhagic fevers (VHFs) are caused by a heterogeneous group of viruses belonging to four taxonomic families and include:

– The filoviruses, Ebola, and Marburg
– The arenaviruses, which can be divided into Old World (Lassa) and New World (Guanarito, Junin, Machupo, Sabia) agents, the latter causing Venezuelan, Argentinian, Bolivian, and Brazilian hemorrhagic fevers, respectively
– The flaviviruses, yellow fever, dengue, Kyasanur Forest, and Omsk
– The bunyaviruses, Crimean-Congo hemorrhagic fever (CCHF), Rift Valley fever (RVF), and a number of hantaviruses which cause hemorrhagic fever with renal syndrome (HFRS; Hantaan, Dobrova, Seoul, and Puumala)

Yellow fever has been known since at least 1647; is distributed throughout tropical Africa, Asia, and South America; and was the first disease shown, by Walter Reed, to be transmitted by mosquitos [12]. The remaining VHFs have, for the most part, been discovered within the last half-century and remain quite limited in their geographic distributions.

Although the VHF viruses share certain microbiologic characteristics (all are lipid-enveloped single-stranded RNA viruses) and derive their name from the fact that some (but not all) patients experience clinically significant hemorrhage, they produce a diverse array of clinical symptoms and vary widely in their virulence. While massive hemorrhage occurs frequently with New World arenaviral infections, as well as RVF, CCHF, certain hantaviruses, and yellow fever, it occurs less frequently with infections due to the filoviruses and rarely in Lassa infections. Renal failure is characteristic of HFRS and yellow fever but otherwise rare. Rash is seen with dengue, Lassa, and filovirus infections, but not with most other VHFs. Icterus is prominent with yellow fever; tremors with the New World arenaviruses; deafness with Lassa. Pulmonary disease is prominent with Kyasanur Forest and Omsk, as well as with certain hantaviruses.

In addition, laboratory findings vary considerably among the VHFs. New World arenaviral infections characteristically cause a profound leukopenia, while HFRS patients often exhibit significant leukocytosis. Thrombocytopenia can be marked in most VHFs but is usually not a prominent feature of Lassa fever. These notable differences in presentation and symptomatology have implications for clinical care and infection control. The prodigious amount of vomiting and diarrhea seen in patients during the 2014–2016 EVD outbreak, coupled with the very low infectious dose and high quantity of viral particles within these bodily fluids, makes meticulous attention to personal protection imperative. Guidelines for the employment of such protection, as well as engineering and other controls, provide the basis for the remainder of this chapter.

It is important to note that the causative agents of most VHFs need be handled under Biosafety Level 4 (BSL-4) conditions in the laboratory [13]. Exceptions include yellow fever, RVF, and the hantaviruses, which require BSL-3 precautions. Patients harboring any of these agents that present the risk of person-to-person transmission ideally should be managed under HLCC conditions. These agents would include the hantaviruses, as well all of the BSL-4 agents except RVF, Kyasanur Forest, and Omsk viruses, which are transmitted to humans only via the bite of infected arthropods.

Facility Design

High-level containment care facilities include enhanced engineering controls with the goal of providing safe and effective care to patients while optimizing infection prevention and control procedures [9]. Two consensus efforts have been conducted to develop recommendations for designing HLCC care units: a US consensus workgroup met in 2005 in order to develop standards for the operation of BCUs and a 2007 European Network for Highly Infectious Diseases (EuroNHID) project [7, 10]. However, formal standards for HLCC facility design features have not been established.

The design of a HLCC unit should serve to minimize nosocomial transmission of infectious diseases by establishing a contained clinical isolation unit capable of housing all facets of patient care. Hallmark HLCC engineering controls include care units that are physically separated from normal patient care spaces and maintained at negative pressure by independent air handling systems. At least 12 air exchanges per hour in patient rooms are accomplished using dedicated exhaust systems with high efficiency particulate air (HEPA)-filtered effluent air. It is recommended that pressure status of patient care rooms be monitored with audible and visual alarms [14, 15]. Individual patient care rooms should have the equipment necessary to support critically ill patients, self-closing doors, and handwashing sinks [7].

It is important to have established zones for employee donning and doffing, storage of personal protective equipment (PPE), and staff shower-out capability [7]. Additionally, selection of nonporous and seamless construction materials is an ideal design component of HLCCs that both minimizes the risk of environmental contamination and maximizes the ability to clean surfaces when contaminated.

HLCC units should delineate high-risk areas ("Hot" or "Red" zones: patient room, laboratory), intermediate-risk areas ("Warm" or "Yellow" zones: anteroom, decontamination area, waste processing, doffing), and low-risk areas ("Cold" or "Green" zones: nurse station, clean supply room, staff egress changing area). Establishment of these designated zones guides healthcare worker flow as well as implementation of protocols for cleaning, packaging of waste or clinical specimens, and decontamination of medical devices, reducing the potential for contamination as personnel and devices move through the HLCC. Inclusion of laboratory and waste sterilization capabilities within HLCC units are also key features that help minimize the potential of transmission throughout the hospital [16, 17]. A double door pass through autoclave was identified as mandatory for HLCC unit through both consensus efforts [7, 18]. Analogous pass through "dunk tanks" filled with disinfectant solution is useful in moving specimens from the HLCC to the laboratory and is particularly useful in facilities which lack a dedicated "in-unit" laboratory. Implementation of telehealth strategies that enable communication with healthcare workers as well as provide a platform for remote patient assessment is important in reducing the number of healthcare workers with direct patient contact, thus limiting risk.

Administration and Support Services

The intermittent and sporadic utilization of HLCC units necessitates strong leadership. Ideally, a HLCC leadership team should possess a robust set of diverse skills to include

expertise in infectious disease and critical care, nursing, emergency management, industrial and environmental hygiene, research, laboratory, hospital administration, and public affairs. This leadership team should meet regularly to strategize and define drill objectives, plan educational efforts, promote research projects, and synchronize collaborative endeavors [19].

A robust activation checklist should be developed and drilled intermittently to assure that departments followed through on tasks assigned and that necessary items can be obtained in a timely fashion. This checklist should address unit stockage and supplies, equipment, medications, facilities activation procedures, and notification of departments and key individuals who will be involved in the activation of the unit and the care of the patient(s).

Numerous communication strategies are adaptable for use by HLCC team members. An electronic alert system with individual key numbers can be used to notify the HLCC team of drills and activation. An email distribution list can be used for less urgent information sharing. In order to organize the response for arriving patients, a modified Hospital Incident Command System (HICS) can be utilized, and the Incident Commander (IC) can support HLCC leaders in completing the activation checklist. Moreover, the IC can facilitate coordination among the multiple agencies often involved in air and ground transport of patients to the patient care unit.

Although each facility may wish to tailor the composition of the HICS team to their own particular needs, and each situation may require adjustment, key team members would typically include logisticians to plan to replenish PPE supply levels and address waste management issues, a public information officer (PIO), medical technical specialists to include infectious disease physicians and nurse leaders to manage the clinical care of the patient and staffing within the patient care unit, a laboratorian to address testing logistics and specimen transport challenges, a clinical research expert to facilitate the use of experimental therapies when necessary, a nurse concierge or other dedicated individual to support family needs, and a behavioral health expert to address staff well-being as well as the psychological and emotional needs of patients and families.

The PIO is charged with responding to media requests, including those from social media sources. Internal messaging within the organization should be done prior to release of any external information. Internal messaging may be directed at administration, employees, and also patients (inpatients and outpatients) and their family members. Press conferences with infectious diseases experts and others involved in patient care should be held to provide timely updates. It is also helpful to establish an information phone line staffed by the state or local health department to answer questions and provide education to the community.

During activation, a concierge nurse or other patient advocate may prove helpful in the support of families of patients. This individual can assist by making advance contact with family members and arranging services such as airport transportation, accommodations, and meals. They can also serve as the liaison with family in the coordination of meetings to discuss the status of the patient, media information, and various other details. Pastoral Care staff should be available upon request during activation.

Staffing: Nursing

The HLCC facilities in the United States that admitted patients infected with Ebola virus disease (EVD) have well developed teams of nurses who are able to provide skilled and effective patient care within their isolation units. Recruiting and retaining qualified nursing staff willing and able to provide care for patients under emotionally and physically demanding HLCC conditions is the cornerstone to building a successful team. The staffing model must take into account the need for specialized nurses to provide quality care. The virulence of the disease in question, its mortality rate, the advanced levels of PPE required, and the propensity for infected patients to require complex interventions all influence the profile of staff selected to care for patients with VHF or other highly hazardous communicable diseases.

The composition of the HLCC nursing team should reflect these needs. The centers in the United States that provided care for EVD patients each required that a percentage of their core nursing staff possess critical care experience, with some institutions relying solely upon critical care nurses to staff their units [20]. In addition to critical care experience, it is essential to have nurses on the core team who have expertise in infectious diseases and have expressed an interest in caring for patients with highly hazardous communicable diseases [21]. The success of the nursing staff starts with a robust selection process. Utilizing a formal interview process to determine qualifications and interest has been proven to be an effective method of selecting staff. Once the interview is complete, the nursing leadership should contact the employee's current manager to discuss their clinical skills, teamwork skills, adaptability, dependability, and critical thinking skills.

When staffing a unit that is only activated intermittently, an important consideration involves creating a process by which staff members can designate their availability on any given day. This can be accomplished in a multitude of ways; however, maintaining a consistent process is key to ensuring staff availability when needed. As the provision of nursing care must occur 24 h a day, 7 days a week, it is important that a schedule be created that accounts for all times. One way to achieve this is to mandate on-call shifts for dedicated staff.

The on-call nurses are required to be at the Unit within 60 min of being notified of activation. Another option is to have each staff member fill out their availability and maintain a balanced schedule several weeks in advance. This allows staff members a level of autonomy to self-schedule.

Considerations for creating a nursing staff matrix include the design of the unit, the waste management strategy, the disease being treated, the acuity of the patient, the level of personal protective equipment (PPE) required, and the time that could be spent in the PPE [20, 22]. An important consideration is the need to minimize the number of staff that enters into the patient care area. The ability to utilize nursing staff in multiple roles can facilitate effective infection control by minimizing the footprint within potentially contaminated areas. In this effort, nursing staff become responsible for tasks that would typically be assigned to ancillary services within the standard hospital system, including routine cleaning and environmental services, phlebotomy, coordinating care needs, and unit clerk roles [20, 23].

Consideration must also be given to the nurse-to-patient ratio necessary to provide safe care to a patient with VHF. The number of staff members required for a standard 12 h nursing shift must take into account the time limitations imposed on each staff member due to the use of advanced PPE. When providing the level of intensive care that these patients can require in addition to wearing PPE, it is necessary to adjust shift times and staffing ratios [24]. The staffing matrix utilized within hospitals that successfully cared for EVD patients differed significantly from standard staffing ratios. Within the Nebraska Biocontainment Unit, six staff members were present on a day shift and five on the night shift (usually three nurses along with respiratory therapists and/or patient care technicians). Healthcare staff was scheduled for 12 h shifts which were broken up into 4 h blocks to allow for the limitation of not wearing PPE for greater than 3–4 h at a time. Designation of roles for each staff member on each shift can clarify expectations and ensure consistency within each role. The use of an autoclave for waste processing may necessitate the inclusion of a dedicated staff member to operate the machine. The Special Communicable Diseases Unit (SCDU) at Emory University utilized two to three nurses to staff the Unit at all times when occupied, and it was recommended that nurses remove ("doff") PPE every 4 h to allow for personal needs and a break. At the highest level of PPE and patient care, three nurses were working in the SCDU at one time, in 12-h shifts. They rotated in 4-h shifts between the patient room, the anteroom, and the nursing desk with each having designated responsibilities [20].

Within each treatment facility, there are unique circumstances which will dictate the most efficient and safe nursing staffing practices. It is important to consider both staff safety and patient safety when determining which guidelines will be used to operate a unit caring for patients with VHF or other highly hazardous communicable infectious disease. Nurses that join these teams must be individuals able to operate outside their normal routine by utilizing critical thinking skills, flexibility, and autonomy. These nurses are required to take responsibility for a wide array of clinical and nonclinical tasks and perform these in demanding clinical situations, which are skills that require practice, exceptional communication, and teamwork.

Staffing: Physicians

Caring for patients with highly hazardous communicable diseases is a true multidisciplinary effort, and choosing and maintaining an effective physician team illustrates this concept well. Each center should tailor their physician team to fit their needs and the culture of the facility. In general, Infectious Diseases specialists have often led physician teams in the biocontainment setting; however this may not be appropriate in every facility. Infectious Diseases specialists monitor and manage infectious complications and coinfections and oversee the administration of antimicrobial agents, including experimental products. Specialists in Critical Care medicine are an important asset in the care of patients with VHF, since some of these patients may have critical illness and require ICU-level care, including mechanical ventilation, vasopressors, and other supportive care measures [25]. Since invasive procedures are often necessary as well, it is critical to ensure that the physician team includes individuals who are experienced and comfortable performing these procedures. This skillset should be assessed by direct consultation with these physicians, since some may not feel comfortable performing invasive procedures in a high-risk isolation environment. Training and drills involving critically ill patients, including performing invasive procedures in PPE, are an integral part of skill assessment and maintenance for the physician team.

It is also important to involve other groups of physicians who may be needed in the care of a patient with VHF. Pediatricians and Pediatric Intensive Care specialists should be identified in the event that a pediatric patient must be cared for under HLCC conditions. Similarly, obstetricians are an important part of the physician team since it is possible that a pregnant and/or laboring patient with suspected or confirmed VHF will need care in the isolation setting. Nephrology specialists have been involved in the care of patients with VHF who developed renal failure, especially those who required dialysis [26]. Relationships with other physician groups, including but not limited to Surgery, Emergency Medicine, General Internal Medicine, and Pathology, should be established as necessary in case consultative needs arise. It is important to note that some physician consultations can occur via telemedicine without the physician

entering the patient care room. This serves to limit the number of physicians required to directly evaluate the patient at the bedside in order to decrease the possibility of exposure.

When considering physician staffing models, it is important to note that physicians providing care to patients with EVD or other VHF in the biocontainment setting may be unavailable for prolonged periods of time. This makes the ability to provide clinical care to other patients very difficult. Thus it is important to consider backfilling other clinical responsibilities in order to provide dedicated time to the complex processes of donning and doffing PPE, performing procedures, and other aspects of biocontainment care. The most appropriate way to provide 24-h on-call coverage for patients with VHF must be evaluated, and this will vary depending on the current call structure in the medical facility [27].

The involvement of physicians in training (fellows, residents, etc.) in the care of patients with VHF in the biocontainment setting has been discussed, and generally it is felt that trainees should not be compelled to provide direct care for patients with VHF as a requirement of a clinical rotation due to excessive risk. However, physicians in training have entered the biocontainment setting on a volunteer basis to observe and assist in the management of patients with VHF via the telemedicine system, which provides educational opportunity without excessive risk.

Personal Protective Equipment (PPE)

The use of PPE in clinical care to prevent the transmission of infectious diseases is not a new concept, yet in the context of viral hemorrhagic fever, PPE became the topic of much debate during the 2014–2016 EVD outbreak. Facilities who were tasked with providing care to infected individuals with EVD faced multifaceted challenges related to the selection, procurement, and proper utilization of PPE, along with changing guidelines.

Personal protective equipment is worn to minimize exposure to infectious material and to protect the skin and mucous membranes from exposure to pathogens. PPE reduces, but does not eliminate, the risk of skin and clothing contamination with pathogens among healthcare personnel [28]. Examples of PPE include items such as gowns, gloves, foot and eye protection, respirators, and full body suits. The Occupational Safety and Health Administration (OSHA) requires that employers protect their employees from workplace hazards that might cause injury. Controlling a hazard at its source is the best way to protect employees. Depending on the hazard or workplace conditions, OSHA recommends the use of engineering or work practice controls to manage or eliminate hazards to the greatest extent possible [29]. Installing negative pressure air handlers to place a barrier between the hazard and the employees is an engineering control; changing the way in which employees perform their work is a work practice control. When engineering, work practice, and administrative controls are not feasible or provide insufficient protection, PPE must be utilized to protect healthcare workers who are providing care to patients with infectious diseases.

There are many variations of PPE available for purchase, and selecting the best version for the environment in which care must be delivered can be daunting. The versions of PPE used in HLCC units differed in the individual pieces used; however, the guiding principles remained the same. For healthcare workers caring for patients with EVD, PPE that fully covers skin and clothing and prevents any exposure of the eyes, nose, and mouth is recommended to reduce the risk of accidental self-contamination of mucous membranes or broken skin [30]. Varying levels of PPE are appropriate for use based upon the acuity of the patient, the volume of infectious bodily fluids (blood, vomitus, diarrheal stool) present, and the potential for aerosolization of these fluids [31]. Providing this level of protection often requires that many pieces of PPE be worn; this can lead to an increased risk of fatigue and overheating.

Centers in the United States that treated patients with EVD in 2014 utilized varying levels of PPE based on this stratified risk assessment [20, 23, 31]. In the Nebraska Biocontainment Unit (NBU), the first level of PPE used completely disposable, and the second level incorporated the use of a powered air-purifying respirator (PAPR). First-level PPE consisted of fluid-impervious Association for the Advancement of Medical Instrumentation (AAMI) level 4 gown, N95 respirator, surgical hood, face shield, knee-high fluid-impervious boots, three pairs of gloves, and the addition of a second splash-resistant apron as needed (Fig. 21.1). The second level of PPE consisted of fluid-impervious coveralls, inner boot liners, outer boot covers, three pairs of gloves, and the PAPR hood with accompanying belt and blower motor. In the Emory University Special Communicable Diseases Unit (SCDU), varying levels of PPE based upon the risk assessment consisted of a completely disposable ensemble as well as a PAPR ensemble. The disposable PPE included a coverall, apron, booties, double gloves, face shield (goggles if face shield is not available), and a surgical mask. The PAPR level of PPE was comprised of a coverall, double gloves, booties, an apron, and the PAPR hood [20] (Fig. 21.2). The equipment available for purchase through each institution may have differed; however, making selections based upon disease transmission and risk factors related to patient care rather than brand-specific products helped to ensure healthcare worker protection.

The donning and doffing procedures require both vigilance and attention to detail. While PPE is effective at decreasing exposure to infected bodily fluids among healthcare workers, these healthcare workers are still at risk if this

Fig. 21.1 First-level PPE worn in the Nebraska Biocontainment Unit (NBU) while caring for patients with Ebola in 2014

Fig. 21.2 PAPR-level PPE worn in the Special Communicable Diseases Unit (SCDU) while caring for patients with Ebola in 2014

equipment is not removed in a manner that prevents exposure [32]. Detailed guidance with the correct order of donning and doffing equipment should be readily visible on a chart posted within the patient care area. The process used to don and doff PPE should be followed exactly by all personnel every time it is performed and should be guided by a checklist. All staff members, regardless of title or position, are expected to hold one another accountable for adhering to the policies and procedures, including the appropriate use of PPE [22, 33, 34]. The donning and doffing process should incorporate the use of a donning partner who assists the healthcare worker in appropriate placement of PPE and a doffing partner who assists the healthcare worker in removing their PPE. This doffing partner helps to ensure that all steps in the process are completed in the proper order and technique. The physical exhaustion and emotional fatigue that can accompany the provision of care for patients infected with VHF may further increase the chance of an inadvertent exposure to bodily fluids on the outside of the PPE when performing the doffing process [32]. The CDC also recommends the presence of a trained observer when performing the doffing process [30]. The trained observer is available to provide immediate feedback if there is any inadvertent contamination of the healthcare worker. The doffing process can be complex and is considered to be a vulnerable area in which the healthcare providers may be inadvertently contaminated. Simulation studies conducted using donning and doffing scenarios have shown high rates of self-contamination during the doffing process, especially during the removal of the gown and gloves, emphasizing the need for stringent protocols and supervision during this process [28].

Transportation

The safe transport and prehospital care of patients with EVD or other highly hazardous communicable diseases require enhanced infection control practices, which necessitate sound administrative policies, work practices, and environmental controls implemented through focused education, training, and supervision [35]. HLCC hospitals require partner emergency medical services (EMS) capable of ensuring the safety of the HLCC transport medics and the public through implementation of infection control practices, policies, and procedures [9].

The ambulance environment is defined by confined space with limited air handling, and care is provided with reusable medical devices in acute situations. Emergency vehicles have many compartments, shelves, patient care beds, and other high-touch areas that are difficult to clean. Ambulance cleaning protocols have been established, but environmental contamination with nosocomial organisms continues to be documented [36–38].

A variety of specialized approaches have been established for HLCC transport. These include specialized truck and trailer ambulances (used in Germany), HEPA-filtered ground

ambulance positioned aboard a Hercules C130 aircraft (Sweden), road ambulances with stretcher-based isolators (Italy), and road ambulances draped to minimize contamination potential (United States) [39, 40]. HLCC transport medics should receive enhanced education and training on modes of transmission, the availability of vaccines, pre- and postexposure prophylaxis, and treatment modalities. Competency-based training has also been recommended to develop and maintain PPE donning and doffing competency [32, 35, 41]. The transporting HLCC ambulance is commonly supported by an external transport team with extra supplies that facilitates communication with external support agencies (which may include law enforcement, airport operations, public health, and emergency management) and provides guidance for clinical decision-making when required [35, 39]. Transition of the patient from the HLCC transport team to the HLCC unit team should be a highly scripted event, rigorously tested through planning and exercise [35].

Following transition of care, the emergency vehicle should be decontaminated. HLCC facilities have utilized different decontamination methods; however the general principles of surface cleaning performed by personnel in PPE followed by appropriate waste disposal are maintained. Vaporized hydrogen peroxide, chlorine dioxide, and ultraviolet light have all been used or proposed as adjunct decontamination strategies for emergency vehicles [40, 42, 43].

Clinical Care

The clinical care of patients with VHF is largely supportive, and the ability to provide supportive care varies depending on the capabilities of the individual healthcare facility. Generally, healthcare centers caring for patients with VHF should be ready to provide general supportive care and additional aggressive intensive care modalities when necessary and available. Up until recently, little information regarding these care modalities was available given that outbreaks of VHF occurred in resource-limited settings. However during the 2014–2016 EVD outbreak, patients who were managed in resourced settings in the United States and Europe where aggressive supportive care was available had a much lower mortality rate when compared with that noted in previous reports from Africa [44].

The clinical presentation of VHF may vary according to the etiology, the wide range of clinical severity, and multiple patient factors. It is important to note that the clinical presentation of VHF is non-specific; therefore it is important to evaluate patients with possible and confirmed VHF for other causes of symptoms, notably including malaria if the patient has a history of travel to an endemic area.

The delivery of aggressive supportive care requires intravenous access, and the availability of this depends on the resource limitations of the healthcare facility. In resource-limited settings, only peripheral IV placement may be feasible, whereas in resourced settings, central venous catheters (CVCs) are generally utilized. The placement of a CVC also enables healthcare workers to obtain blood samples without repeated venipuncture, reducing the risk of sharps injuries.

Antipyretic agents have been utilized to manage fever in patients with VHF. Oral rehydration solutions and/or intravenous fluids may become necessary given the profound volume depletion that can result from vomiting and diarrhea. Pharmacologic controls such as antiemetic and antidiarrheal medications have been utilized to control nausea, vomiting, and diarrhea. Physical controls such as emesis bags and fecal management systems have been employed as well, since controlling these secretions is an important infection control modality in the healthcare setting.

The monitoring and replacement of electrolytes is also an important aspect of supportive care in patients with VHF, since significant electrolyte disturbances have been observed [45]. Nutritional support is often necessary, and when available, total parenteral nutrition has been utilized in patients with anorexia, nausea, and vomiting.

Patients with respiratory symptoms may require supplemental oxygen. Bleeding complications can be treated with blood products and correction of coagulopathy. Cases of encephalitis have been observed, and patients with agitation may require sedating medications. Patients with VHF may also develop secondary infectious complications including bacterial sepsis, and these infections may be managed with antimicrobial therapy, which is often empiric since the availability of blood cultures is limited [46].

Patients with VHF may present with, or may progress to, critical illness involving multi-organ failure and may require advanced life support including mechanical ventilation and dialysis. These interventions were utilized during the care of patients with EVD in the United States and Europe during the 2014–2016 outbreak [44]. In patients with respiratory failure, airway management was accomplished via intubation by rapid sequence induction and video laryngoscopy [27, 47]. Renal failure was managed with continuous renal replacement therapy (CRRT) in some centers. Vasopressors have been utilized for blood pressure support in patients with VHF. An assessment of the use of other advanced cardiac life support measures like cardioversion and chest compressions should be discussed by healthcare facilities preparing to care for patients with VHF, with consideration of the potential benefits to the patient and the risks to healthcare workers.

There are currently no FDA-approved therapeutic agents available for the treatment of Ebola or Marburg virus disease, although many experimental drugs were used in the treatment of patients with EVD during the 2014–2016 outbreak. Since most of the use of these agents was employed in individuals and very small groups of patients, no definite

conclusions can be made regarding efficacy. Nonrandomized single-arm trials were conducted in Africa evaluating certain therapeutics; however one was unable to reach any conclusions on the potential benefit of the viral RNA polymerase inhibitor favipiravir, and another evaluating the small interfering RNAs product TKM-130803 did not demonstrate improvement in survival [48, 49]. A randomized trial involving the triple monoclonal antibody cocktail ZMapp was conducted, but although the estimated effect appeared beneficial, the result did not meet the statistical threshold for efficacy [50]. Similarly, convalescent serum has been used in the management of patients with EVD; however one study did not demonstrate a significant improvement in survival in patients administered convalescent plasma [51]. Ribavarin has been shown to be effective in treatment of Lassa fever [52].

The hospital discharge of patients with VHF is a complicated process and is dependent on many factors, including resolution or significant improvement of symptoms along with correlative virologic laboratory data. Consultation with local and state health authorities and the CDC and/or WHO should occur to determine the recommended disease-specific discharge criteria for patients with VHF.

Laboratory Support

The monitoring of laboratory parameters is a vital part of providing supportive care to patients with VHF, since these patients may have significant laboratory abnormalities on which clinical management is based. This is especially important in patients who are critically ill who require interventions like dialysis where laboratory parameters must be evaluated frequently and closely monitored. The ability to perform laboratory testing in a safe and effective manner requires significant planning prior to implementation.

As a first step, the clinical care team should discuss which laboratory studies are necessary in order to care for the patient with VHF. This potential testing menu should be communicated to laboratory leadership, who should assess each test to determine if the sample can be processed safely. It is essential that the clinical care team have access to a menu of available laboratory tests and detailed information on the collection of specimens, including any special media required or recommended collection times.

Determining the location of the laboratory should take into account the capabilities of the facility. If feasible, laboratory testing should be performed in close proximity to the site of clinical care to eliminate the need for specimen transport, thereby increasing safety and decreasing turnaround time [19, 53]. Point-of-care testing is desirable but is often not comprehensive, and additional testing may need to occur in the core laboratory or a special containment laboratory. It is important

to note that some special containment laboratories may not have the equipment necessary to perform routine laboratory studies such as complete blood counts or metabolic panels, so these tests may need to be performed in the core laboratory if point-of-care testing is not available. A careful risk assessment should occur prior to implementation of any testing in order to minimize risk to the instruments and most importantly the laboratory staff [17].

Viral load monitoring is helpful in patients with VHF, as the degree of viremia may predict the initial severity of disease and provide information on progression of disease during the treatment phase. The viral load is generally a component of discharge criteria as well [54, 55]. The transport of samples to the appropriate reference laboratory for viral load testing is a complicated process, and significant preplanning is necessary in order to facilitate this.

Waste Management

The importance of stringent infection prevention and control, including environmental infection control, is heightened when providing HLCC for patients with VHF due to factors such as low infectious dose and potentially large volume of body fluids containing high concentrations of viral particles. These elements contribute to the significant yet manageable hazards posed by such care. Perspectives and waste management strategies of two HLCC facilities have been reported [16]. Robust packaging and disinfection procedures were employed by these two facilities in order to process EVD-associated solid and liquid patient waste, contaminated patient linens, healthcare worker PPE and linens, contaminated medical devices, and other general medical waste.

Waste, linens, medical equipment, and other items potentially contaminated with pathogens such as Ebola, Lassa, Marburg, and select other VHFs are categorized as Category A Infectious Substances through the United Nations and US Department of Transportation's Hazardous Materials Regulations [56]. Category A Infectious Substances require enhanced packaging and labeling along with security plans in preparation for transport [57]. Materials that are sterilized by autoclaving or incineration are not required to be packaged and shipped as Category A Infectious Substances.

The quantity of waste generated through HLCC is significant with reports of over 1,000 lb of waste generated per patient [58]. Management of such large quantities of infectious waste requires scalable strategies for packaging, storage, and security. Solid waste disposal strategies include autoclaving and incineration. It is important to maintain autoclave validation logs to ensure appropriate function. Several strategies have been employed for the transport of waste from the patient care room, including double bagging of waste and wiping the outside of the bag with bleach prior

to transport. Storage in waste-holding containers may be necessary while awaiting transport to the autoclave or incinerator. According to current recommendations, liquid waste can be safely disposed of in the sewer system. However, during the 2014–2016 Ebola outbreak, some facilities utilized pretreatment strategies with a hospital-grade disinfectant prior to disposal of liquid waste [16]. Fluid solidifiers were also used at some facilities in order to dispose of liquid waste into the solid waste stream. Waste should only be handled by trained individuals in full PPE [59].

Environmental cleaning during and after the care of patients with VHF is an important part of protecting healthcare workers, as well as other patients in the facility by maintaining the highest infection control standards. Environmental cleaning for many VHFs, including Ebola, should only be performed by trained individuals, and full PPE should be worn at all times during this process. Daily cleaning of HLCC facilities generally consists of surface cleaning with an EPA-registered disinfectant approved for use against non-enveloped viruses [60]. The terminal cleaning process varies by facility but generally consists of disposal of waste followed by surface cleaning with a hospital-grade disinfectant and disinfection of medical equipment. Some facilities utilize a final decontamination step involving ultraviolet germicidal irradiation or vaporized hydrogen peroxide [16, 61]. This process should be monitored and documented by a trained infection control expert to ensure compliance with all procedures.

Care of the Deceased

The remains of a patient with Ebola virus disease (EVD) are considered highly infectious. It is important to remember that although the patient is deceased, the viral load may remain very high, and body fluids may remain infectious for an extended period of time postmortem [62]. There is significant risk for those who are handling the body if proper procedures and barriers are not employed. Preparing the body for transportation to the mortuary must be done by trained staff in the patient care room as close to the time of death as possible [63].

When providing care for the deceased in the United States, it is most likely that these patients will be in a hospital setting and more stringent controls can be implemented. In addition to federal laws and guidelines that apply to mortuary workers, mortuary practices may also be subject to a variety of state, tribal, territorial, and local regulations. CDC recommends close collaboration with public health officials in the state or local jurisdiction, as well as with the licensed funeral director who has agreed to accept the bagged remains, to safely implement each step of the process [63]. The presence of a memorandum of understanding (MOU) with key ancillary partners can facilitate safe and timely transfer of the remains of deceased patients. It is beneficial for any insti-

tution that may provide care for patients with VHF to have an MOU in place with a local mortuary service, crematorium, or cemetery.

The highly infectious nature of the remains of a deceased victim of EVD demands the use of increased protection for the healthcare worker. The recommended PPE for handling such remains includes a powered air-purifying respirator (PAPR), fluid-impervious coveralls, double gloves, and use of an outer apron [64]. Adequate staffing during the care of the deceased is essential for safe execution of the procedures. The patient remains are first prepared and packaged within the patient room (hot zone) and transferred out into the hallway or anteroom (warm zone) and out of the patient care area (cold zone) for transport to final disposition [65]. The body of the deceased should not be washed or embalmed, medical devices should remain in place, and healthcare workers should not attempt to remove them. Autopsies should not be performed unless specifically directed by the state health department and only after consultation with the CDC and state health department officials [63]. Patient remains should be securely contained within the patient care area. The remains should be packaged using established guidance, which currently includes the use of multiple layers [63]. The first layer to form a protective barrier is a standard hospital issued mortuary bag, followed by a heat sealable chlorine-free material, and final securement is achieved by the use of a heavy duty morgue bag. Each protective barrier that is added should be thoroughly disinfected before moving to the next step and again before being transported out of the hot zone. The patient remains should be transferred out of the hot zone with special attention paid to minimizing the cross contamination of zones.

When the remains have been safely processed out of the patient care area, the transport team will assume care of the deceased. The composition of the transport team will vary; however it is important to consider state requirements for chain of custody when developing protocols. Personnel serving on the transport team may include the servicing mortuary staff, state medical examiner, healthcare worker or leadership staff, and law enforcement personnel. Cremation is recommended [63]. Upon completion of cremation, the ashes may be returned to the family of the deceased as the risk of transmission of infection is no longer present [63]. When providing care for the deceased patient, the utmost level of dignity and respect for the deceased patient and his/her family should be maintained.

Evaluation of Persons Under Investigation (PUI)

During the 2014–2016 Ebola outbreak, many healthcare facilities were faced with caring for patients who presented with symptoms compatible with EVD and met certain

epidemiologic criteria as defined by the CDC [66, 67]. These patients were termed "persons under investigation."

In order to properly address quick isolation and care of persons under investigation for EVD or other VHF, a travel and symptom triage tool is needed at check in areas within the healthcare environment. The tool can be a paper instrument with simple questions related to travel history and symptoms. Alternatively, a more robust tool can be built within the electronic health record (EHR) to assess travel history, identifying specific countries and providing decision support prompts that then are matched up with presenting symptoms and correlated with CDC case definitions. Alerts then appear within the EHR to notify caregivers of additional precautions required (e.g., give patient mask to wear, notify Infectious Diseases experts, isolate patient in a negative pressure room, etc.). Whatever tool is used, it must be agile and quickly adapted to meet ever-changing emerging pathogen threats.

Once a patient screens positive for travel history and symptoms matching the CDC case definition, a process map can be used to provide step-by-step guidance to healthcare providers using a standardized approach. A protocol should be created for the Emergency Department, as well as for other ambulatory locations (outpatient clinics, radiology, etc.) where patients may present with symptoms. A positive screen result for epidemiologic risk and signs or symptoms consistent with viral hemorrhagic fever should trigger escalating personal protective equipment use and movement to a designated isolation area. The choice of isolation area is determined by each individual facility. A predetermined area within the Emergency Department can be utilized since this is often the point of entry for patients [68]. Notification of appropriate personnel should then occur, including Infection Control professionals, area leadership, a designated Infectious Diseases physician, public health officials, and the laboratory.

Once the patient is isolated, security should be summoned to control the area and to maintain a log of staff entering the isolation zone. Staff in PPE then perform an initial assessment of the patient and obtain additional details and history, including confirmation of epidemiologic history. Specialists may be called in to assess the patient as well, or alternatively this may be accomplished via video technology in an effort to limit the number of individuals who enter the room. Once the exam is completed, a consultation with local public health and CDC should be conducted, and testing requirements should be determined. It is important to ensure that the appropriate collection methods are utilized; these should be clarified with the public health laboratory prior to specimen collection [69].

A PUI may require imaging studies. Bedside studies are preferred from an infection control perspective but are not comprehensive, and additional studies that cannot be performed at the bedside may be necessary. Robust predefined plans for patient transport to cardiac catheterization, CT, MRI, and endoscopy should be developed. In addition, a PUI may require surgical intervention. A predefined plan should be created, which outlines the preoperative timeout briefing, intraoperative care considerations to include type of PPE to be used by the surgical team, instrument handling and care, recovery of patient in the operating room, and subsequent cleaning and disinfection of the space, instruments, and waste management [70]. Although there are no formal guidelines for the management of patients with suspected VHF in the operating room, there is information available from the American College of Surgeons, who recommends against elective surgical procedures but states that emergency operations can be considered [71]. Development of these processes along with defined drills involving the operating room staff will enhance the capability to successfully navigate through care of PUIs in need of surgical care.

Special Populations

Children differ from adults in myriad ways which potentially impact their vulnerability to the viral hemorrhagic fevers and present challenging management issues. Developmentally, children are likely to be frightened by the sight of caregivers in PPE and may flail, tug, and pull at such equipment, creating additional risk for these caregivers. Similarly, young children are unable to cooperate with their management, and the usual pediatric paradigm of family-centered care, which would enlist parents in assisting with such care, may be prohibitively hazardous in the setting of transmissible VHF such as Ebola, Marburg, or Lassa.

From a policy perspective, multiple factors complicate the care of children. Certain medications that might be used in adults are contraindicated in children, are unavailable in liquid preparations, or are unfamiliar to pediatric practitioners. Similarly, the use of investigational drugs may be more problematic in children. Finally, pediatric-specific equipment, doctrine, and HLCC beds are often lacking.

Despite these apparent disadvantages, children have been consistently underrepresented among Ebola victims. In the 1995 Kikwit outbreak, children accounted for 27 of the 315 cases (9%), despite constituting 50% of the Zairean population [72]. Similar findings were obtained during the 2000 outbreak in Gulu, Uganda, where children represented 20 of the 218 cases (9%) [73]. Moreover, these children had a case fatality rate of 40%, not dissimilar to the rate among adults. Finally, in a study performed in Guinea during the 2014–2016 outbreak, 147 of 823 cases (18%) occurred in children, again despite the fact that children constitute 50% of the population of Guinea [74]. While these findings raise the possibility that children may be less susceptible to infection

with Ebola (and, perhaps, with other VHFs), it is likely that this diminished susceptibility derives mainly from social factors; young children are less likely to function as primary caregivers to dying family members, are thus less likely to have contact with body fluids, and are less likely to participate in intimate funereal preparations.

Management of the pregnant or laboring patient with VHF is similarly problematic; maternal and infant mortality are extraordinarily high in virtually all of the VHFs, although maternal survival has been reported following fetal loss associated with Ebola infection and uterine evacuation has been shown to improve survival of pregnant women with Lassa fever [75, 76]. Fetal and neonatal loss among women with Lassa fever has been reported to be as high as 87%, and there are no reports of neonates born to Ebola-infected mothers surviving beyond 19 days [76, 77]. Vertical transmission of yellow fever appears to occur very rarely, and few reports of affected pregnant women exist for the remaining VHFs [78]. In light of this paucity of information, it is difficult to make specific recommendations for the management of the pregnant woman with VHF. Nonetheless, meticulous planning must be undertaken by facilities that might be called upon to care for pregnant VHF patients. Such planning should address, among others, questions regarding where and when delivery should occur, what equipment is required, and how complications like bleeding should be managed.

This final question that raises, perhaps, the most vexing issue associated with the care of newborns and children with contagious VHFs is under what circumstances might parents or other nonmedical caregivers be permitted to remain at the beside of an infected child. Parents might assist in reducing the anxious flailing of a toddler, thereby diminishing risk to HCWs. They are also afforded the opportunity to participate in family-centered care, thus emotionally benefitting both parent and child. These considerations must be balanced, however, against the reality that parents then become, in a sense, additional patients, requiring assistance in donning and doffing PPE and running the risk of inadvertent breaks in containment by non-skilled individuals. An expert panel recently met to discuss these considerations, although the subject is likely to remain controversial [79].

Maintenance of Preparedness

Training healthcare workers in the provision of care to patients with VHF presents many challenges. One of the challenges involves maintaining readiness and keeping team members engaged when these specialized patient care areas are not activated. The implementation of a consistent and structured training schedule facilitates staff engagement by incorporating activities of varying intensity. Incorporating complex functional exercises, tabletop exercises, skill-focused drills, competency evaluations, and team-building activities builds a strong foundation from which the patient care team can further develop. Educational sessions on emerging infectious diseases may also be helpful to maintain readiness and interest. Developing an annual training calendar that is available to team members in advance sets the expectation for the team members and also helps to minimize scheduling conflicts for required attendance. Bringing healthcare workers together to train regularly enables the formation of a cohesive functional team rather than a collection of individuals.

When considering the provision of intensive care to patients with EVD, the challenges are heightened. These patients often require invasive interventions which involve the skills of anesthesiologists and critical care physicians, as well as nurses proficient in managing the ongoing care of critically ill patients. The interventions must be implemented while wearing advanced levels of PPE, thus potentially limiting the dexterity of the providers. Training regimens for healthcare workers should allow for the development and refinement of specific policies and procedures, addressing critical issues like donning and doffing PPE, waste processing, the insertion of central venous catheters, endotracheal intubation, the use of continuous renal replacement therapy, Advanced Cardiac Life Support (ACLS) and Pediatric Advanced Life Support (PALS) plans and protocols, and the plan for extraction and provision of care for a provider who has a medical emergency in the patient care area. Providing routine training for key personnel ensures the opportunity for healthcare workers to gain confidence in their ability to perform the procedures, as well as to build a firm foundation of processes for many aspects of care [22]. Developing and exercising detailed policies to guide cares within the unit, as well as maintaining an expert staff, are key components to maintaining preparedness.

Training ensures that healthcare workers are knowledgeable and proficient in donning and doffing PPE before caring for a patient with VHF. Comfort and proficiency when donning and doffing are only achieved by repeatedly practicing correct use of PPE. When providing training and assessing competency in PPE, healthcare workers should perform required duties while wearing PPE. This could include inserting an intravenous device, assisting with perineal care after an incontinent episode, processing waste in the patient care area, or charting an assessment. Training should be customized for the intended audience and effectively relay essential information. Healthcare workers who are unwilling or unable to fulfill these requirements should not be included in the patient care team.

With regard to maintenance of skills, it is imperative that a culture of safety be fostered within the care team, where the focus is on effective teamwork to accomplish the goal of safe, high-quality patient care [80]. All staff must feel

empowered to identify and take action to prevent errors from occurring and to improve the patient care environment. This sense of empowerment can be developed during routine training and preparedness exercises in preparation for the reality of patient care.

Conclusions and Future Directions

The provision of care for patients with EVD or other VHF is a complex process necessitating that close attention be paid to multiple infection control modalities. Engineering and facility controls such as negatively pressurized rooms within designated care areas are ideal; however the most important assets needed to provide safe and effective care for patients with VHF or other highly hazardous communicable diseases are a trained team and a collection of well-developed and practiced protocols.

In order to increase preparedness for highly hazardous communicable diseases in the United States following the Ebola outbreak of 2014–2016, the CDC and Department of Health and Human Services (DHHS) developed a three-tiered system to screen and manage patients with suspected or confirmed EVD. Under this system, facilities with high-level containment care capability are designated as "Ebola Treatment Centers" (ETC). As of this writing, approximately 55 such centers have applied for designation and funding; among them are ten designated as regional referral centers by DHHS (one in each of its ten geographic regions) [81]. In addition, other hospitals would be designated as "Ebola Assessment Hospitals" (EAH), able to manage and isolate persons under investigation (PUI) until a diagnosis of Ebola virus disease (EVD) can be confirmed or refuted. Finally, remaining hospitals ("Frontline Facilities") would receive training in order to improve their ability to isolate potential Ebola victims until they could be transferred to an EAH or ETC. Within this network, the provision of patient care can be optimized, protocols practiced and improved, and research on investigational drugs and products streamlined. Although this system represents a vast improvement in hospital preparedness in the United States, isolation bed capacity remains limited [82].

The US Department of Health and Human Services, the Assistant Secretary for Preparedness and Response (ASPR), the Centers for Disease Control and Prevention (CDC), and Emory University, Nebraska Medicine, and Bellevue Hospital Center comprise the National Ebola Training and Education Center (NETEC) [83]. Initiated in 2015, the NETEC program supports the education and training of healthcare facilities in order to enhance preparedness for Ebola and other highly infectious diseases. Although there remains a significant amount of education and work to be done in this area, this collaborative effort, along with the tiered network of hospitals, represents a significant improvement in preparedness.

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