



Published in final edited form as:

Curr Opin Infect Dis. 2015 August ; 28(4): 343–348. doi:10.1097/QCO.000000000000176.

Ebola Virus Disease: Preparedness and Infection Control Lessons Learned from Two Biocontainment Units

Angela L. Hewlett, MD, MS¹, Jay B. Varkey, MD², Philip W. Smith, MD¹, and Bruce S. Ribner, MD, MPH²

¹Division of Infectious Diseases, Department of Medicine, University of Nebraska Medical Center, Omaha, NE

²Division of Infectious Diseases, Department of Medicine, Emory University School of Medicine, Atlanta, GA

Abstract

Purpose of Review—This review details infection control issues encountered in the management of patients with Ebola Virus Disease (EVD), with emphasis on how these issues were confronted in two biocontainment patient care units in the United States.

Recent Findings—There is a notable paucity of medical literature to guide infection control policies and procedures when caring for patients with EVD. Thus, the experience of the Serious Communicable Diseases Unit (SCDU) at Emory University Hospital and the Nebraska Biocontainment Unit (NBU) at the University of Nebraska Medical Center serves as the basis for this review. Facility issues, staffing, transportation logistics, and appropriate use of personal protective equipment is detailed. Other topics addressed include the evaluation of patients under investigation (PUI) and ethical issues concerning the safe utilization of advanced life support.

Summary—This review intends to serve as a reference for facilities that are in the process of creating protocols for managing patients with EVD. Given the lack of literature to support many of the recommendations discussed, it is important to utilize the available referenced guidelines, along with the practical experiences of biocontainment units, to optimize the care provided to patients with EVD while strictly adhering to infection control principles.

Keywords

Ebola; preparedness; infection control; biocontainment

Introduction

The largest outbreak of Ebola virus disease (EVD) began in West Africa in December 2013. As of April, 2015, 11 patients with EVD have been treated in the United States; seven of these 11 patients were treated in the Serious Communicable Diseases Unit (SCDU) at

Corresponding Author: Dr. Angela Hewlett, 985400 Nebraska Medical Center, Omaha, NE 68198, phone: (402)559-8650, fax: (402)559-5581, alhewlett@unmc.edu.

Conflicts of Interest: none

Emory University Hospital and the Nebraska Biocontainment Unit (NBU) at the University of Nebraska Medical Center.

Caring for patients with EVD presents unique management issues and requires input from multiple individuals and services within the healthcare system. One element of this specialized care that deserves significant attention is the role of infection prevention and control. There are many facets of infection prevention involved in the care of patients with EVD, including the use of an appropriate facility, delivery of medical care in personal protective equipment, safe transport, laboratory processing of specimens, waste management, and provisions for care outside of the biocontainment facility. All of these infection control issues should be thoroughly evaluated and approached in a multidisciplinary manner in order to safely provide care for patients with EVD.

The Facilities

Although biocontainment patient care units like the SCU and the NBU are not necessarily needed to treat a patient with EVD [1], specific features in the design of these facilities make them ideal environments to effectively treat patients with EVD while minimizing the risk of transmission to healthcare workers, other patients, and the public [2]. The individual patient care rooms are designed to deliver a level of care equivalent to that of a standard intensive care unit (ICU) allowing healthcare workers to provide aggressive supportive care. To maintain staff safety, the units include dedicated space for staff changing areas and to store personal protective equipment (PPE). Patient care rooms are also constructed with seamless surfaces for walls and floors to facilitate surface disinfection. To maintain the safety of patients with EVD as well as the safety of other hospitalized patients and healthcare workers, the biocontainment units are located in secured areas of their respective facilities that are separate from normal patient care areas. All entrance and exits in the unit are continuously monitored and limited only to healthcare workers and other individuals cleared to be on the unit.

The SCU and NBU are also designed to safely care for patients with respiratory diseases that, unlike Ebola, can be spread through the airborne route. Specifically, air in the patient rooms is under net negative pressure in relation to the surrounding areas. Air in the patient rooms has laminar air flow across the patient bed. All air from patient rooms undergoes high-efficiency particulate air (HEPA) filtration before being 100% exhausted to the outside. The outside exhaust is geographically separate from any hospital air intake locations, and is high enough to allow for dilutional disbursement.

Staffing

Independent of the specific characteristics of the treatment facility, establishing a trained, competent, interdisciplinary team of providers and emphasizing a culture of safety are critical to effectively care for patients with EVD [3,4]. To staff the SCU and NBU, a core team of physicians, nurses and other healthcare workers, with expertise in infectious diseases and critical care and an expressed interest in caring for patients with serious communicable diseases, were identified. In order to be part of the team, all providers were required to demonstrate a commitment to practice a culture of safety. In a culture of safety,

all team members commit to strictly adhere to safe and effective practices outlined in standard operating protocols and are empowered to ask questions and voice concerns as they arise [3]. Team members were also required to meet the following criteria: 1. Participate in regularly scheduled drill exercises; 2. Demonstrate competency in infection control practices with specific emphasis on protocols for donning and doffing PPE, specimen handling, and waste management. Providers who were unable to demonstrate these competencies were not allowed to provide direct patient care to patients with EVD. Drills, training sessions, and competency verification are performed every three to six months

Laboratory

In addition to the core group of physicians and nurses, laboratory technologists are critical members of the interdisciplinary team required to safely care for patients with EVD. Guidelines from the Centers for Disease Control and Prevention (CDC) state that hospital clinical laboratories can safely handle specimens from patients with EVD if risk mitigation strategies (engineering controls, administrative and work controls, use of appropriate PPE) are implemented [5]. However, the American Society for Microbiology (ASM) has issued guidelines suggesting that specimens from patients with EVD should be limited to point-of-care (POC) testing equipment and performed either in the patient's room or in a biological safety cabinet in an isolated area [6]. The SCDU established a self-contained POC laboratory and processed all specimens within a 4-foot laminar flow biosafety containment hood [7]. The NBU performed a detailed risk assessment and determined that closed manual or automated chemistry and hematology analyzers could safely be used to test specimens with potential Ebola virus outside of a biosafety level 3 (BSL-3) laboratory [8]. Based on this risk assessment, other specimens were either tested in a point-of-care laboratory located inside the NBU or safely packaged and transported to the Nebraska Public Health Laboratory [8]. Specimens for shipment were packaged in concordance with United States Department of Transportation (DOT) guidelines using a basic triple packaging system consisting of the following 1. A primary container (sealable specimen container) wrapped with absorbent material; 2. A secondary container (watertight, leak-proof); 3. An outer shipping package. All testing should be performed by a clinical pathologist or a clinical laboratory technologist specifically trained in the safe handling of infectious pathogens to minimize any risk of a laboratory-based transmission.

Waste management

Hospitals preparing to care for patients with EVD also require a multidisciplinary team to develop standard protocols for the management of medical waste. This team should include environmental services, infection prevention and control, biosafety officers, hospital administration and others with expertise in hazardous waste disposal. All waste from patients with EVD is disposed of in compliance with local, state and federal regulations. EVD patient care waste is defined and regulated by the United States DOT as a category A infectious substance. Therefore, all solid medical waste generated in the care of patients with EVD in the SCDU and NBU was sterilized in an autoclave which allowed the waste to be safely transported and disposed as regular medical waste [9]. While CDC guidelines state that liquid waste may be disposed of without treatment into sanitary sewers [10], local waste

treatment authorities may have different requirements. It is essential to communicate with local authorities to ensure that local requirements are met. Both the SCDU and the NBU add a disinfectant to all liquid waste prior to disposal in the sanitary sewer.

Transportation

Safe transport of patients with EVD requires significant planning and collaboration. To prepare for the transportation of a patient with EVD, it is advisable to conduct a full-scale drill in order to ensure that appropriate protocols and procedures are in place.

Patients may initially travel via Air Medical Transport (AMT), which involves a specialized aircraft designed to provide medical care while ensuring the safety of the staff and crew. AMT has been utilized to medically evacuate patients with EVD from West Africa as well as to transport patients with EVD within the United States to biocontainment units. Guidelines on transporting patients with EVD via AMT are available [11].

Ground transportation should involve multiple partners in order to ensure the safety of the patient, the crew, and the public. These include public health agencies (local, state and national), emergency medical services, law enforcement agencies, and the transporting and receiving facilities. Ground transport usually involves the use of an ambulance. It is recommended that the ambulance be draped with an impervious barrier or otherwise modified to decrease the possibility of contamination of the vehicle during transport [12,13]. Strict infection control practices should be followed during all phases of transport, including the use of appropriate PPE for both the patient and the healthcare workers, and separation of the driver compartment from the passenger compartment [14]. Decontamination of the ambulance following transport involves the application of an EPA-registered hospital grade disinfectant to the interior of the ambulance, the stretcher, any exposed equipment and all exterior surfaces of the waste bags [13]. Consideration should also be given to appropriate waste disposal following transport [12]. It is important to establish an incident command structure in order to coordinate communications during the transportation process.

Personal Protective Equipment

The selection of appropriate PPE is an integral step in caring for a patient with EVD. Issues such as availability, tolerance and the condition of the patient must be considered in the selection process. Tolerance is of utmost importance, since healthcare workers caring for patients with EVD often remain in PPE for longer periods of time than in traditional settings, and this PPE can be cumbersome. This should be carefully assessed via training and drills prior to caring for a patient with EVD.

The exact PPE utilized for caring for a patient with EVD may vary based on availability and the facility. However, there are several general principles that deserve recognition. PPE should be located in a designated area where there is ample room for donning prior to entering the patient care area. Healthcare workers should wear hospital-issued scrubs under their PPE. If non-disposable scrubs are utilized, plans should be made for appropriate cleaning of these after use. Healthcare workers should have no skin exposed while caring for a patient with EVD. Options include impermeable surgical gowns and head covers, or

coveralls. Two sets of gloves should be worn, including an outer glove that has extended cuffs. The NBU utilizes an additional set of patient care gloves for use while providing direct patient care. Shoe/boot covers should be worn, and an apron can be used when there is a high risk of exposure to body fluids. Respiratory protection may include a PAPR or N-95 respirator together with a face shield to protect the face [15].

Inappropriate donning and doffing of PPE can lead to contamination, therefore it is imperative to allow for supervision and active participation in these activities by donning/doffing partners. These individuals are tasked with ensuring that PPE is donned and doffed appropriately while utilizing the highest adherence to principles of infection control. This process should be meticulously performed; following well delineated and practiced protocols at all times. Although they are not performing direct patient care, the doffing partner is at risk of contamination, therefore they should be wearing PPE that is appropriate for patient care.

Although not specifically required, our experience indicates that healthcare workers feel more comfortable showering after doffing their PPE and prior to exiting the biocontainment facility. Based on practical experience and feedback from the patient care team members, the SCU and NBU also provides undergarments so it is not necessary for the healthcare workers to wear any of their own personal clothing into the patient care areas.

More specific guidance on donning and doffing procedures including videos and photos of PPE used at the biocontainment facilities at Emory University Hospital and The University of Nebraska Medical Center as well as CDC training videos can be found at: <http://www.nebraskamed.com/biocontainment-unit/ebola> <http://www.emoryhealthcare.org/ebola-protocol/videos.html> <http://www.cdc.gov/vhf/ebola/healthcare-us/ppe/training.html>

Identifying and Evaluating Patients under Investigation (PUIs) for Ebola Virus Disease

A 'patient under investigation' is a patient who fits clinical and epidemiologic criteria for EVD. It is important for healthcare facilities to prepare for the evaluation of PUIs, including designating a place where this evaluation will occur and educating the front-line providers who will be tasked with triaging and managing these patients [16].

The PUI case definition includes the presence of an elevated body temperature or subjective fever, severe headache, fatigue, muscle pain, vomiting, diarrhea, abdominal pain, or unexplained hemorrhage. The patient must also fit epidemiologic criteria, which include having been in a country with widespread transmission or cases of EVD or having been exposed to a patient with EVD within 21 days prior to onset of symptoms [17]. These questions should be addressed on initial evaluation. Although a patient may fit the case definition, there are many other illnesses that can cause the above-mentioned signs and symptoms, and a thorough history and physical exam should be performed in order to evaluate the patient for other potential etiologies of their illness.

If EVD is suspected, the patient should be placed in a private room with a private bathroom or a bedside commode. State and local health authorities should be notified, as well as the hospital's infection control program. Healthcare workers should don PPE appropriate for the patient's condition. When caring for stable patients who are not bleeding, vomiting, or having uncontrolled diarrhea, this should include a face shield, surgical face mask, impermeable gown and two pairs of gloves. Enhanced PPE, including that recommended for confirmed EVD patients, may be necessary depending on the clinical status of the patient. Once appropriate PPE is donned, the healthcare worker should further assess the patient with a comprehensive history and physical exam. Dedicated equipment should be utilized during the patient evaluation. It is especially important to create protocols for the provision of safe care to special populations like pediatric and obstetrical PUIs, who may present additional management challenges [18,19].

The decision to test for EVD and/or to discharge a patient under investigation should be made in consultation with the local and/or state health authorities. Such patients will normally be under active surveillance by the local health department. It is important to note that due to the low sensitivity of the reverse transcription-polymerase chain reaction (RT-PCR) test result for Ebola virus in patients experiencing symptoms for less than 72 hours, a negative RT-PCR test within this time period does not rule out EVD. Therefore if an initial RT-PCR test is performed and is negative, a second test should be performed after 72 hours of symptoms in order to effectively rule-out EVD.

Advanced Life Support in Patients with EVD

Patients with EVD may be critically ill and require intensive care. EVD patients in the United States and other developed countries have required and received aggressive support interventions like mechanical ventilation and dialysis [20]. These interventions can be performed in a safe manner with meticulous attention to maintaining infection control precautions, including the appropriate use of PPE. Protocols for these procedures should be created and practiced by the healthcare providers who will perform them. Guidance on the provision of critical care for patients with EVD is available [21].

Other interventions, including defibrillation, likely represent limited risk to HCWs when infection control protocols are followed. Cardiopulmonary resuscitation (CPR) is generally regarded as having an unfavorable risk-benefit ratio due to the potential for release of body fluids during chest compressions. Discussions surrounding these ethical issues are available in the medical literature [22]. These decisions and policies should always be discussed in-depth with the patient and family members, optimally as soon as possible during the patient's hospitalization.

Provisions for care outside of the biocontainment unit

Another issue that deserves discussion is whether to transport a patient outside of the treatment unit for surgery, radiologic studies [23,24], childbirth or other interventions. It is highly desirable to perform all possible interventions at the bedside; however, whether a patient with EVD should be transported outside of the treatment unit must be considered on a case-by-case basis after a careful risk/benefit analysis. The clinical status of the patient and

the acuity of the need for the intervention must be weighed against the risks to the healthcare workers, other patients, and the facility. If transporting a patient with EVD outside of the isolation unit would place other patients and the facility at undue risk, the patient should remain in the isolation unit [2]. In our experience thus far, patients with EVD did not require interventions that could not be performed at the bedside, therefore patients remained in the isolation unit throughout their hospital stay.

Conclusion

Caring for patients with EVD necessitates careful preparation and a multidisciplinary team-oriented approach to provide aggressive supportive care for the patient while maintaining the highest level of safety for healthcare workers and protecting the public. It is imperative that the utmost attention be paid to infection control issues in all stages of this process. Although data to support many of the practices referenced in this paper are limited, we hope that our experiences in the care of patients with EVD will stimulate further research to optimize the safe management of patients with serious communicable diseases.

Acknowledgments

We would like to thank the dedicated staff members of the Nebraska Biocontainment Unit and the Emory Serious Communicable Diseases Unit for creating and maintaining the highest standards for safety and patient care.

Financial Support: This project was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health Award Number UL1TR000454 (Atlanta Clinical and Translational Science Institute).

References

1. Centers for Disease Control and Prevention. Interim Guidance for Preparing Ebola Treatment Centers [Internet]. 2014. [updated 2014 Dec 15]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/preparing/treatment-centers.html>
2. Smith PW, Anderson AO, Christopher GW, et al. Designing a biocontainment unit to care for patients with serious communicable diseases: a consensus statement. *Biosecur Bioterror*. 2006; 4(4): 351–65. [PubMed: 17238819]
- 3*. Feistritz NR, Hill C, Vanairsdale S, Gentry J. Care of patients with Ebola virus disease. *J Contin Educ Nurs*. 2014; 45(11):479–81. Feistritz et al describe the key factors in selecting staff for the Emory SCU and detailing the training they underwent prior to caring for patients with EVD. [PubMed: 25365183]
- 4**. Schwedhelm S, Beam EL, Morris RD, Sebastian JG. Reflections on interprofessional team-based clinical care in the ebola epidemic: the Nebraska medicine experience. *Nurs Outlook*. 2015; 63:27–29. In this important publication, Schwedhelm et al highlight the importance of team-based professional care and ongoing training for the NBU staff. The importance of establishing a culture of patient safety is emphasized. [PubMed: 25645479]
5. Centers for Disease Control and Prevention. Guidance for US laboratories for managing and testing routine clinical specimens when there is a concern about Ebola virus disease [Internet]. 2015. [updated 2015 Mar 19]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/laboratories/safe-specimen-management.html>
6. American Society for Microbiology. Interim laboratory guidelines for handling/testing specimens from cases or suspected cases of hemorrhagic fever virus (HFV) [Internet]. 2014. [updated 2014 Sep 10]. Available from : <https://www.asm.org/images/PSAB/Ebola9-10-14.pdf>
- 7*. Hill CE, Burd EM, Kraft CS, et al. Laboratory test support for ebola patients within a high-containment facility. *Lab Med*. 2014; 45(3):109–11. In this concise report, Hill et al detail the

specific instruments and standard operating protocols used to establish the point-of-care laboratory in the Emory SCDU.

- 8*. Iwen PC, Smith PW, Hewlett AL, et al. Safety considerations in the laboratory testing of specimens suspected or known to contain Ebola virus. *Am J Clin Pathol.* 2015; 143(1):4–5. In this editorial, Iwen et al discuss the risk assessment performed at the University of Nebraska Medical Center to determine whether specimens from patients with EVD would be processed in the NBU, hospital core laboratory or public health laboratory. [PubMed: 25511134]
- 9**. Lowe JJ, Gibbs SG, Schwedhelm SS, et al. Nebraska Biocontainment Unit perspective on disposal of Ebola medical waste. *Am J Infect Control.* 2014; 42(12):1256–7. In this commentary, Lowe et al describe the process used by the NBU to safely dispose waste generated caring for patients with EVD. [PubMed: 25465251]
10. Centers for Disease Control and Prevention. Procedures for safe handling and management of Ebola-associated waste [Internet]. 2014. [updated 2014 Dec 12]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/cleaning/handling-waste.html>
11. Centers for Disease Control and Prevention. Guidance on air medical transport (AMT) for patients with Ebola virus disease (EVD) [Internet]. 2015. [updated 2015 Jan 27]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/emergency-services/air-medical-transport.html>
- 12*. Lowe JJ, Jelden KC, Schenarts PJ, et al. Considerations for safe EMS transport of patients infected with Ebola virus. *Prehosp Emerg Care.* 2014 [Epub ahead of print] The authors describe the planning, training and coordination by the NBU and Omaha Fire Department's emergency medical services to safely transport patients with serious communicable diseases.
- 13**. Isakov A, Miles W, Gibbs S, et al. Transport and management of patients with confirmed Ebola virus disease. *Ann Emerg Med.* 2015 (in press). This paper reviews procedures necessary for the safe transport of patients with EVD. Appropriate training, PPE, and emergency vehicle preparation and decontamination are detailed.
- 14*. Isakov A, Jamison A, Miles W, Ribner B. Safe management of patients with serious communicable diseases: recent experience with Ebola virus. *Ann Intern Med.* 2014; 161(11): 829–30. In this opinion piece, the authors describe the planning, training and coordination by the SCDU and Grady emergency medical services to safely transport patients with serious communicable diseases. [PubMed: 25244492]
15. Centers for Disease Control and Prevention. Guidance on personal protective equipment to be used by healthcare workers during management of patients with Ebola virus disease in U.S. hospitals, including procedures for putting on (donning) and removing (doffing) [Internet]. 2014. [updated 2015 Feb 12]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html>
- 16**. Wu HM, Fairley JK, Steinberg J, Kozarsky P. The potential Ebola-infected patient in the ambulatory care setting: preparing for the worst without compromising care. *Ann Intern Med.* 2015; 162(1):66–7. In this opinion piece, the authors discuss the process developed by the Emory Healthcare ambulatory clinics to safely evaluate patients under investigation for Ebola. [PubMed: 25329137]
17. Centers for Disease Control and Prevention. Case definition for Ebola virus disease (EVD) [Internet]. 2014. [updated 2015 Jan 26]. Available from: <http://www.cdc.gov/vhf/ebola/healthcare-us/evaluating-patients/case-definition.html>
- 18**. Ericksson CO, Uyeki TM, Christian MD, et al. Care of the child with Ebola virus disease. *Pediatr Crit Care Med.* 2015; 16:97–103. This article discusses unique issues encountered in the management of children with EVD. Guidance on advance planning, patient placement, infection control issues and clinical monitoring are detailed. [PubMed: 25647119]
- 19*. Meaney-Delman, D.; Koonin, LM.; Jamieson, DJ. U.S. hospital preparedness for obstetrics patients with possible Ebola. *Am J of Obstetrics and Gynecology.* 2015. (in press). This paper details how pregnant patients with possible EVD should be evaluated and managed
- 20**. Connor MJ Jr, Kraft C, Mehta AK, et al. Successful delivery of RRT in Ebola virus disease. *J Am Soc Nephrol.* 2015; 26(1):31–7. In this important publication, Connor et al describe the protocol for the first known successful delivery of renal replacement therapy in a patient with EVD treated in the Emory SCDU. Processes undertaken to decrease the risk of secondary transmission to healthcare workers are emphasized. [PubMed: 25398785]

- 21*. Johnson DW, Sullivan JN, Piquette CA, Hewlett AL, Bailey KL, Smith PW, Kalil AC, Lisco SJ. Lessons Learned: Critical Care Management of Patients With Ebola in the United States. *Crit Care Med*. 2015 (in press). This paper describes some of the issues encountered in the management of patients with EVD who are critically ill.
- 22*. Halpern SD, Emanuel EJ. Ethical guidance on the use of life-sustaining therapies for patients with Ebola in developed countries. *Ann Intern Med*. 2015; 162:304–05. This editorial discusses ethical issues behind the use of life-sustaining therapies in patients with EVD. [PubMed: 25545099]
- 23*. Auffermann WF, Kraft CS, Vanairsdale S, et al. Radiographic imaging for patients with contagious infectious diseases: how to acquire chest radiographs of patients infected with the Ebola virus. *AJR Am J Roentgenol*. 2015; 204(1):44–8. The authors describe in detail (including schematic diagrams) the protocol used in the Emory SCU to acquire chest radiographs for patients with EVD. [PubMed: 25402496]
- 24*. Moreno CC, Kraft CS, Vanairsdale S, et al. Performance of bedside diagnostic ultrasound in an Ebola isolation unit: the Emory university hospital experience. *AJR Am J Roentgenol*. 2015; 204:1–3. In this article, the use of bedside ultrasound for the care of patients with EVD in the Emory SCU, and the process used to disinfect equipment, is described. [PubMed: 25539228]

Key points

- Biocontainment facilities have design features that allow healthcare workers to effectively treat patients with EVD while minimizing the risk of secondary transmission.
- An interdisciplinary team that commits to maintaining a culture of safety, adheres to strict infection control practices and demonstrates competency in donning and doffing personal protective equipment is critical to the safe and effective clinical care of patients with EVD.
- Hospitals preparing to care for patients with EVD must develop and practice policies and procedures to manage laboratory specimens and waste, transport patients, identify and evaluate patients under investigation and provide, if appropriate, advanced life support safely.