ORIGINAL ARTICLE

Current Capabilities and Capacity of Ebola Treatment Centers in the United States

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OBJECTIVE. To describe current Ebola treatment center (ETC) locations, their capacity to care for Ebola virus disease patients, and infection control infrastructure features.

DESIGN. A 19-question survey was distributed electronically in April 2015. Responses were collected via email by June 2015 and analyzed in an electronic spreadsheet.

SETTING. The survey was sent to and completed by site representatives of each ETC.

PARTICIPANTS. The survey was sent to all 55 ETCs; 47 (85%) responded.

RESULTS. Of the 47 responding ETCs, there are 84 isolation beds available for adults and 91 for children; of these pediatric beds, 35 (38%) are in children's hospitals. In total, the simultaneous capacity of the 47 reporting ETCs is 121 beds. On the basis of the current US census, there are 0.38 beds per million population. Most ETCs have negative pressure isolation rooms, anterooms, and a process for category A waste sterilization, although only 11 facilities (23%) have the capability to sterilize infectious waste on site.

CONCLUSIONS. Facilities developed ETCs on the basis of Centers for Disease Control and Prevention guidance, but specific capabilities are not mandated at this present time. Owing to the complex and costly nature of Ebola virus disease treatment and variability in capabilities from facility to facility, in conjunction with the lack of regulations, nationwide capacity in specialized facilities is limited. Further assessments should determine whether ETCs can adapt to safely manage other highly infectious disease threats.

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In September 2014, identification of the first case of a patient with Ebola virus disease (EVD) to present in the United States was delayed and infection of 2 healthcare workers (HCWs) occurred.[1] This experience exposed the difficulty that hospitals faced in adequately training dedicated staff to care for patients with EVD. Historically, institutional responses to highly infectious disease (HID) events have modified existing policies, procedures, and resources. However, this approach resulted in increased risks of HCW occupational exposure and delayed critical laboratory testing.[2] Consensus reports from the European Network of Infectious Diseases and state and federal agencies in the United States, as well as experts from the 3 initial biocontainment patient care units in the United States, have identified key elements in the design and operation of specialized facilities caring for patients with HIDs,[2,3] including EVD. These units, defined by the European Network of Infectious Diseases as high-level isolation units, include recommendations for infection control, clinical competency, physical features, facility workflow, and worker safety protocols to prevent disease transmission to HCWs, other patients, and the general public.[2,3]

To maximize HCW safety and domestic EVD isolation capacity, the Centers for Disease Control and Prevention established an unprecedented multitiered network of hospitals with specialized capabilities for Ebola care, including frontline facilities, Ebola assessment hospitals, and Ebola treatment centers (ETCs).[4] ETCs have largely been designated in metropolitan areas that receive significant amounts of travelers

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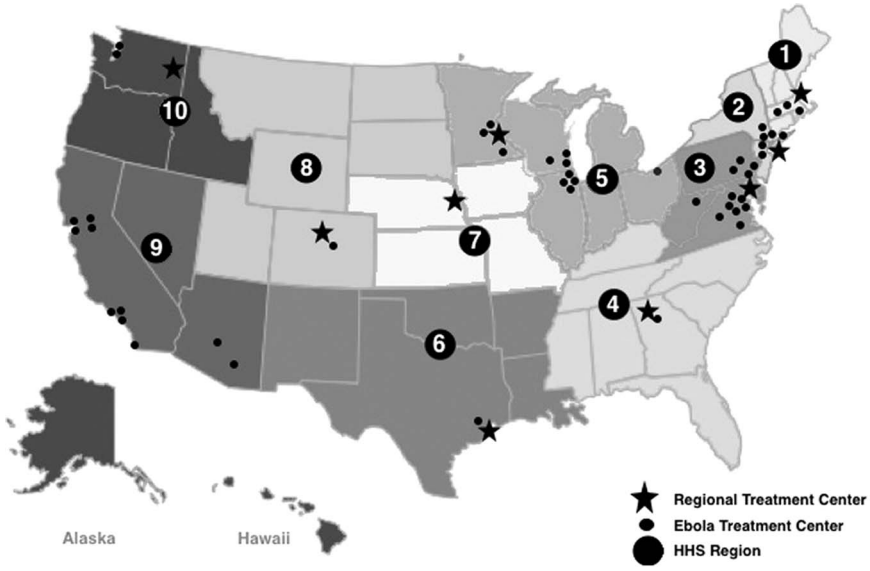

FIGURE 1. US Department of Health and Human Services (HHS) Regions with Centers for Disease Control and Prevention–designated Ebola Treatment Centers and Assistant Secretary for Preparedness and Response–designated Regional Ebola and Other Special Pathogen Treatment Centers.

from West Africa, leaving sparsely populated areas in further proximity from ETCs (Figure 1).

To ensure rapid readiness to provide Ebola care, local public health officials and the Centers for Disease Control and Prevention coordinated site visits to potential ETC hospitals, assessed facility readiness in 11 augmented capabilities, and provided technical assistance, as needed. As of August 2015, 55 US hospitals designated as ETCs have acquired the enhanced operational capabilities detailed in Table 1.

To further geographic reach and strengthen capacity to care for patients with HIDs, in June 2015 the US Department of Health and Human Services selected 9 ETCs to serve as Regional Ebola and Other Special Pathogen Treatment Centers (RTCs) for patients with Ebola and other HIDs, in conjunction with their respective public health departments (Figure 1). The Assistant Secretary for Preparedness and Response funded the RTCs to expand their operational capabilities and capacity to sustain ongoing readiness throughout the United States.[10] Among other requirements, ETCs selected as RTCs must have the capacity to treat at least 2 Ebola patients at one time, have respiratory infectious disease isolation capacity or negative pressure rooms for at least 10 patients, accept patients within 8 hours of being notified, be able to treat both pediatric and adult patients, and conduct quarterly trainings and exercises for facility staff.[11]

The extensive operational requirements and comprehensive treatment protocols required to care for an EVD patient limit an ETC's capacity. The treatment of patients with EVD and other HIDs in ETCs with proper operational capabilities is critical to nationwide preparedness and the safety of the patient, HCWs, and the community. The recent Ebola epidemic was a grave example of the severity of HID threats, exacerbated owing to increasing global fluidity. This report describes current ETC locations, their infection control infrastructure, and their capacity to care for EVD patients.

METHODS

In April 2015, a 19-question electronic survey (with institutional review board exemption UNMC IRB #165-15-EX) was sent to all 55 ETCs, including the 9 RTCs. The survey was re-sent 2 weeks later to follow up with facilities that had not responded. The survey inventoried current capabilities and capacity as well as the cost of establishing the ETCs; the latter is the subject of another manuscript, currently under review. This survey, which consisted of discrete responses with the ability to provide qualitative feedback for every question, was adapted from existing assessment questions developed by the European Network of Infectious Diseases.[12] The survey included questions regarding isolation unit location within the facility, overall capacity for care, and infection control infrastructure. To assess capacity for care, the maximum number of EVD or HID isolation rooms and beds that can be used simultaneously as well as the total capacity for adult and/or pediatric patients were requested. The number of isolation beds per million of population was calculated using the most recent census estimates.[13] To assess the features of the infection control infrastructure, respondents were asked about separate air handling units, physical barriers separating isolation rooms within the same unit, negative pressure, high-efficiency particulate air (HEPA) filtration, details about entrances and exits to the isolation unit, and the processes used

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TABLE 1. CDC Guidance on ETC Capabilities

Capability	Description
(1) Operations coordination[5]	• ETCs utilize an emergency management structure for hospital communication with state and local public health agencies, healthcare coalition partners, employees, patients, and the community to ensure timely response to facility needs and accurate information dissemination.
(2,3) Staffing and training[5]	• ETCs are operated by interdisciplinary teams of clinical and nonclinical personnel able to sustain weeks of clinical care with strategies to minimize the number of staff in direct contact with patients.[6] • Personnel are trained specifically for their ETC role and demonstrate competency in proper waste management, infection prevention and control, safe processing and transport of laboratory specimens, and proficiency in donning and doffing PPE. • ETCs conduct functional core exercises of processes and establish continuous training programs and retraining for infection control breaches.
(4) Clinical competency[5]	• ETCs have a level of clinical expertise and readily available consultation not often found in routine clinical settings.[3] ETC staff are familiar with clinical protocols for patients with EVD and have ready access to experienced clinical EVD specialists.
(5) PPE[5]	• ETC staff have drilled and demonstrated proficiency in critical donning and doffing PPE procedures. Each step of the PPE donning and doffing process is supervised by a trained observer to ensure proper protocol compliance.[7]
(6) HCW safety[5]	• ETCs have implemented policies and procedures for HCW safety. This includes compliance with all state and federal occupational safety standards, and the assurance of direct active monitoring of HCWs caring for patients with EVD or those in contact with the contaminated environment or waste for signs and symptoms potentially consistent with EVD throughout patient care and for 21 days afterwards.[7] Such monitoring is overseen by public health officials for all healthcare professionals in direct patient care.
(7) Laboratory[5]	• ETC laboratories have implemented risk assessments of safe work practices, PPE requirements, laboratory equipment, and instrumentation.[2,8] • ETCs have the capability to safely process laboratory specimens on-site. This requires appropriate laboratory procedures and protocols, a dedicated space, possible point-of-care testing, equipment, staffing, reagents, necessary training, and specimen transport.
(8) Infrastructure[5]	• ETCs have designated private patient care rooms with dedicated in-room bathrooms or covered bedside commodes, as well as dedicated patient-care equipment. • ETC patient rooms are equipped with separate designated areas for donning and doffing PPE, allowing sufficient space for trained observers to verify proper fit and technique.[7]
(9) Transportation[5]	• In collaboration with state and local public health agencies, and emergency medical services providers, ETCs have established interfacility transportation plans and logistical details of safe patient transport from the ambulance entrance to the ETC. • Designated EMS providers and the ETC transport team have been adequately trained for their roles and demonstrate proficient donning and doffing of PPE.
(10,11) Waste management and environmental services[5]	• ETC personnel are trained in fundamental infection control practices, including the proper handling and storage of category A infectious waste. • Personnel require direct supervision for the cleaning and disinfecting processes of patient care areas and equipment, using EPA-registered hospital disinfectants. • Waste contaminated with EV is classified as a category A infectious substance, which requires the proper containers and procedures for safe handling and storage, and a waste management vendor capable of transporting category A infectious substances, with the exception of waste autoclaved prior to transport, which would then classify it as category B waste.[9]

NOTE. CDC, Centers for Disease Control and Prevention; EMS, emergency medical services; EPA, Environmental Protection Agency; ETC, Ebola treatment center; EV, Ebola virus; EVD, Ebola virus disease; HCW, healthcare worker; PPE, personal protective equipment.

for sterilization of medical waste. Data were coded and analyzed using descriptive statistics with an electronic spreadsheet (Excel; Microsoft).

RESULTS

Forty-seven (85%) of the 55 ETCs, including 7 of the 9 RTCs, completed the survey. Thirty-eight ETCs are located in academic teaching institutions, 5 are in referral hospitals providing specialized tertiary care, and 2 designated themselves "other." Nearly all (44 [94%]) of the high-level isolation units are located within the main hospital building. A portion of ETCs have separate wards (20 [43%]) or separate rooms within another ward (24 [51%]); 3 facilities (6%) are standalone. Of the 20 units located on isolated wards, 14 (70%) have separate air-handling systems. Of the 24 units located within other wards, 14 (58%) have independent air-handling systems and 23 (96%) have a physical barrier separating the isolation rooms from the rest of the ward.

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TABLE 2. High-Level Isolation Unit Capacity of the 47 Ebola Treatment Centers Participating in the Survey

Variable	No. of hospitals	Total no. of high-level isolation rooms	Total adult bed capacity	Total pediatric bed capacity	Average no. of high-level isolation units per Ebola treatment center
Overall[a]	47[b]	121[c]	84	91	2.6
Children's hospitals	9	35	0	35	3.9
Hospitals treating only adults	13	23	23	0	1.8
Hospitals treating adults and children	24	61	61	56	2.5

[a]Some can be used simultaneously.
[b]Of the 47 facilities, 46 provided separate adult and pediatric bed capacity numbers.
[c]One facility listed only their maximum isolation bed capacity (2) but did not specify whether the beds could be used for pediatric patients.

Of the 47 responding ETCs, there is a total of 84 adult beds, 35 pediatric beds in children's hospitals, and 56 pediatric beds in hospitals treating both adults and pediatric patients (Table 2). Twenty-four hospitals accept both adult and pediatric patients; the children's hospitals designated as ETCs have only pediatric beds available. The mean maximum number of beds that can be used simultaneously by individual ETCs is 2.6. The average capacity of the 7 RTCs that completed the study is shown in Table 3 and is higher than that of non-RTCs. On the basis of the current US census,[13] the number of staffed isolation beds available from the survey respondents is 0.38 beds per million population. Several centers provided additional feedback that capacity varies depending on the HID being treated and that staffing is insufficient for their current bed capacity.

Anterooms and negative pressure (no. of air exchanges per hour: mean, 14.3; median, 12) are available for 45/47 (96%) of high-level isolation units. Consensus guidelines for high-level isolation recommend separate entrances and exits for units, which are available in 23 units surveyed (49%), whereas 24 (51%) use the same pathway for staff to enter and exit.[2] Thirty-one facilities (66%) use HEPA filtration in the units, of which 4 (13%) filter only intake air, 13 (42%) filter only exhausted air, and 13 (42%) have HEPA filtration for both intake and exhausted air. One facility did not specify the HEPA filtration direction.

Eleven ETCs (23%) have the capability to sterilize waste on site, of which 10 have an autoclave and 1 unit is equipped with an incinerator. However, this ETC noted they do not use the incinerator but use a separate certified facility for the disposal of category A infectious waste. Of the 11 ETCs equipped with on-site sterilization capability, 5 (45%) are located within the unit. Six ETCs noted that they were in the process of acquiring and installing an autoclave or intended to do so if they received the funds. All 36 facilities without the capability to sterilize waste on site have processes for category A waste disposal with certified facilities. Only 10 (21%) of the 47 ETCs have isolation units equipped with negative pressure, an anteroom, on-site sterilization of waste, and HEPA filtration. Forty-five ETCs indicated their willingness to participate in the US Highly Infectious Disease Consensus Network to establish control metrics, competencies, and peer review for high-level isolation units.

TABLE 3. Comparison of the Ebola Virus Disease Treatment Capacity of the 7 Regional Treatment Centers and 40 Non-Regional Treatment Centers Participating in the Survey

	Non-Regional Treatment Centers[a]			Regional Treatment Centers		
Variable	Overall bed capacity	Adult bed capacity	Pediatric bed capacity	Overall bed capacity	Adult bed capacity	Pediatric bed capacity
Total	97	60	74	24	24	17
Average	2.4	1.5	1.9	3.4	3.4	2.4

[a]One facility listed only their maximum isolation bed capacity (2) but did not specify whether the beds could be used for pediatric patients.

DISCUSSION

Before the establishment of ETCs, the great majority of hospitals were inadequately prepared to care for a patient with suspected or confirmed EVD.[2,5] Although the development of 55 ETCs has heightened nationwide preparedness levels, the treatment paradigm necessary for EVD care drastically limits patient capacity in these facilities. Furthermore, because no pediatric EVD patients have been treated in the United States, questions remain on the resources, staffing levels, and care required for pediatric patients. Responses show most ETCs distinguish adult bed capacity from pediatric beds and many ETCs do not plan to care for pediatric patients (Table 2), highlighting the need to distinguish between pediatric and adult bed capacity and capability.

Limitations to capacity include both beds available in high-level isolation units and the need for dedicated multidisciplinary staff. Expectations for staff include low turnover rates, regularly scheduled drill exercises for staff to maintain competency in infection control procedures, and a leadership system based on the incident command model.[2,7,14] Despite efforts to designate specific team roles and minimize the number of staff in direct contact with the patient and/or infectious secretions, large numbers of staff are needed to care for an individual patient. Furthermore, owing to the intensity of treatment for EVD and the extended use of personal

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protective equipment, Nebraska Biocontainment Unit staff, for example, rotate after every 2–4 hours to prevent physical and mental fatigue.[15] Because staff participation in ETCs is voluntary, scheduling and backfill issues may further complicate staffing.[7] An additional challenge is how facilities will sustain a fully trained team when unoccupied.

Another unanticipated concern for ETCs has been the logistical capabilities and regulatory requirements associated with processing and disposing of EVD medical waste.[16,17] The challenges of medical waste may be one of the factors that limit an ETC's ability to manage more than one EVD patient at a time. Although autoclaves and incinerators, which cost approximately US $100,000 to install,[15] can transform Ebola virus category A infectious waste to category B waste, only 11 facilities have on-site autoclaves or incinerators. The other 36 facilities must develop expensive procedures for safe handling and use a vendor capable of off-site transport and disposal of category A waste, which could cost millions of dollars.[5,9,15] ETCs without the ability to manage waste on site through autoclaves or incinerators heighten exposure risks during management, packaging, and transporting of contaminated materials.[18] Even with autoclaves and incinerators, the immense amount of waste generated by a single EVD-patient requires a temporary waste storage area/site and a nearly constant sterilization process.[9]

The establishment of the Centers for Disease Control and Prevention's national Ebola network has heightened US preparedness for EVD, but questions on the use and efficacy of these isolation units in response to other diseases remain. Several ETCs noted that if patients are admitted into units located within the same ward as other hospital activities, surrounding rooms will be closed, likely resulting in lost revenue. Beyond the physical number of beds available, it is the negative pressure rooms, physical barriers, staffing capability, and other infection control capabilities that determine a facility's capacity to treat a specific disease. HEPA filtration is not required for isolation of patients with EVD but has been recommended for high-level isolation units.[2,3] Furthermore, having negative pressure rooms, on-site waste sterilization, and an anteroom reduces the risk of disease transmission to HCWs and has been attributed to successfully treating an EVD patient.[16,17]

Although EVD is a highly infectious viral hemorrhagic fever that can be spread to others via infected body fluids, it is not as contagious as some other HIDs spread via the airborne route, such as severe acute respiratory syndrome and Middle East respiratory syndrome coronaviruses, which can be spread through respiratory droplets and fomites.[19–22] Furthermore, the number of travelers from affected nations arriving in the United States varies greatly. An average of 130 to 150 people travel from West Africa to the United States each day,[23] while between March 16 and April 3, 2003, more than 220,000 passengers traveled to the United States from severe acute respiratory syndrome–affected China, Vietnam, and Singapore.[24] Given the more than 121 simultaneous available beds nationwide, it is probable that the ability to control and treat a national outbreak of EVD (albeit unlikely) is adequate, whereas controlling and treating an airborne HID would be challenging.

This study has limitations. Data were self-reported by facility representatives and results were not validated. Many facilities noted their response was Ebola specific and would change with other diseases. Therefore, results cannot be generalized to the capacity for other HIDs. At the time of the survey distribution, RTCs had not yet been designated. The establishment of these centers included requirements on increased capacity. As such, the inclusion of any further capacity development by these facilities is not included here, and therefore the average capacity per RTC is likely greater than as indicated in Table 3. Lastly, these figures do not account for the 9 ETCs that did not respond to the survey, nor were non-ETCs that have made similar preparations but are not designated as ETCs counted; hence the complete number of beds available in the United States could not be tabulated.

The 2014-2015 Ebola epidemic was a reminder of the increasing global fluidity of HID threats. Multilevel, interprofessional collaboration to isolate HID cases and reduce disease transmission will be crucial to contain future outbreaks.[7,25] Although the current capacity of ETCs in the United States is adequate to manage and treat the few sporadic cases of EVD that occur or are treated domestically, future HID pandemics or larger domestic outbreaks warrant surge capacity owing to the low number of patients who can be treated simultaneously in the existing facilities. Finally, although ETCs have acquired specialized capabilities and infrastructure to successfully treat and manage EVD, whether or not these units can be adapted for other HIDs is unknown and should be explored.

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