

Responding to the Global Threat of High-Consequence Pathogens: Protecting Health Care Workers and Caring for Patients

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In the 40 years since the discovery of the Ebola virus, there have been 24 outbreaks, none of which has ever infected more than 450 people at a time (1). The 2014 to 2016 epidemic, which spread quickly across West Africa, infected more than 28,000 people and killed at least 11,000, quickly eclipsing all previous outbreaks combined. What was initially believed to be an isolated outbreak in Guinea crossed international borders for the first time, sparking outbreaks in neighboring Sierra Leone and Liberia and even in noncontiguous countries such as Nigeria, Senegal, and Mali. Sporadic cases among travelers returning from the region to North America or Europe elicited tremendous fear and exposed significant underlying susceptibilities within the North American and European infection control systems (1). Ebola has put the world on notice that rapid globalization has connected communities in such a way that emerging infectious diseases, once categorized as “tropical” in nature, are now worldwide threats that require urgent global responses.

Included among the 28,639 people infected in the most recent epidemic were 881 health care workers, 551 of whom died. The loss depleted an already precious resource, as Liberia, Guinea, and Sierra Leone were already among the countries with the lowest number of health care workers per capita (1 for every 1,597 people in Guinea, 3,472 people in Liberia, and 5,319 people in Sierra Leone) (2, 3). Decades of civil conflict and extreme poverty decimated the health care and sanitation infrastructures of those countries, creating a

flammable milieu ripe for nosocomial transmission of Ebola to health care workers. The lack of readily available laboratories capable of performing validated Ebola diagnostics complicated two critical aspects of administrative infection control: patient triage and isolation. Additionally, unreliable supply chains of basic necessities such as chlorine, gloves, gowns, face masks, and training in standard precautions and infection control further impaired the ability of health care workers to safely care for an infected patient. In effect, the lack of adequate infection control not only put health care workers at risk but also made it difficult to provide the necessary care.

Given that 3 billion people travel by air each year, it was inevitable that an infected passenger would spark an outbreak in an unsuspecting country, as occurred in Nigeria, Spain, and the United States (4). In September 2014, the infection of two health care workers in Dallas caring for an Ebola-infected patient who had recently traveled from Liberia exposed susceptibilities in the infection-control system of hospitals in the United States. In response to this cluster and the growing epidemic in West Africa, the Centers for Disease Control and Prevention galvanized a national effort to identify a select number of facilities in each state with augmented capacity to safely provide comprehensive care to a patient infected with Ebola or another high-consequence pathogen (5).

The article by Garibaldi and colleagues (pp. 600–608) in this issue of *AnnalsATS* describes the construction and implementation

of one such biocontainment unit at the Johns Hopkins Medical Center in Baltimore (6). Although thus far it has only been used to rule out persons under investigation, the Hopkins unit appears to have achieved a critical balance between health care provider safety and the ability to provide effective patient care.

On the basis of consensus recommendations and visits to three of the four preexisting U.S. biocontainment units (6), the Johns Hopkins facility, with three patient rooms and a four-patient capacity, is located away from other clinical areas to preserve normal patient flow and prevent nosocomial transmission. The layout, aided by separate donning and doffing rooms and visual cues at each door, ensures unidirectional flow of staff and materials to reduce cross-contamination. Air-handling systems were implemented to allow for the care of infections that are spread by contact, droplet, and airborne routes. There is a graded pressure system from outside to inside the biocontainment unit that ensures air flow proceeds from outside the unit into the main corridor, from the corridor into the donning and doffing rooms, and then into the patient rooms, in which airflow exceeds the requirement of 12 air changes per hour for all rooms.

A significant obstacle in the care of a patient infected with a high-consequence pathogen is the handling of Category A medical waste. In patients with Ebola virus disease, the volume of diarrhea can exceed 10 L in a single day (7). Although there are limited data on the use of

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autoclaves for decontamination of patient-related waste, the Johns Hopkins team validated one approach using biological indicators embedded within mock patient trash loads. The publication of these methods will be important in advancing the management of highly infectious waste. Additionally, to facilitate cleaning of rooms, the walls and floors in patient care areas were heat-welded and seamless. These environmental infection control details are crucial for decreasing pathogen burden in health care areas and thus mitigating health care worker exposure and infection.

A well-designed and safe biocontainment unit does more than protect health care workers—it also provides a safe space that allows staff members to provide uncompromised patient care. A number of features in the Johns Hopkins unit transcend infection control and allow for a higher level of care. The use of a sophisticated digital stethoscope permits cardiac, pulmonic, and abdominal auscultation while wearing a powered air-purifying respirator—something that most providers were unable to do in West Africa or in other biocontainment units in the United States. An on-site laboratory allows for rapid blood chemistry, hematology, and blood gas testing.

In more cases than not, individuals returning from West Africa with suspected Ebola have an alternative cause for their illness. So that the fear of Ebola does not delay the provision of appropriate care, the Johns Hopkins biocontainment unit is

supported by advanced diagnostic resources, including polymerase chain reaction testing for respiratory and blood pathogens, to evaluate patients for more common diseases while also ruling out Ebola.

The Johns Hopkins biocontainment unit models an innovative approach that builds off of the foundation of experience from preexisting units in the United States. However, there are very few data to support this or any other approach. The lack of evidence-based guidelines in infection control for high-consequence pathogens is itself a global weakness. It is critical that hospital-based biocontainment units, such as the one constructed by Johns Hopkins and others, when not occupied by a patient, be used to generate data on effective infection control practices and inform the safe and effective care of patients with high-consequence pathogens. The authors pledge to do just that and plan, in a collaboration with Clinical and Facilities Engineering, to examine the efficacy of air-handling systems in containing airborne pathogens; they are partnering with the Johns Hopkins Center for Bioengineering Innovation and Design and Jhpiego (an international nonprofit health organization affiliated with Hopkins) to test prototypical personal protective equipment. Data from these initiatives will not only impact the design of future biocontainment units in resource-rich health care facilities but also help international response teams managing outbreaks in the field.

Before the 2014 to 2016 Ebola outbreak, there were four designated biocontainment facilities in the United States, with a combined total capacity of 9 to 11 beds that could be used to treat patients infected with a high-consequence pathogen. Now, as a consequence of the efforts of the Centers for Disease Control and Prevention, there are approximately 121 isolation beds in the United States. There is an opportunity now, before the next infectious disease crisis, to use existing biocontainment units to drive the science on infection control for high-consequence pathogens forward.

Although this and similar units are technological (albeit pricey) marvels, it should not be acceptable that such innovations only be available in resource-rich countries. An effective global solution to fast-spreading contagious diseases must include the development of appropriate health care resources in places where such outbreaks are most likely to emerge—places where the health care infrastructure may be threadbare and easily overwhelmed. In such regions, what is required more than high-tech biocontainment units is an investment in quality medical education, improved access to needed medications, and supply and support of basic laboratory services. Lower-cost solutions applied where global outbreaks start may be even more effective than high-cost solutions meant to keep them from hurting us. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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