Addressing Infection Prevention and Control in the First U.S. Community Hospital to Care for Patients With Ebola Virus Disease: Context for National Recommendations and Future Strategies

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Health care personnel (HCP) caring for patients with Ebola virus disease (EVD) are at increased risk for infection with the virus. In 2014, a Texas hospital became the first U.S. community hospital to care for a patient with EVD; 2 nurses were infected while providing care. This article describes infection control measures developed to strengthen the hospital's capacity to safely diagnose and treat patients with EVD. After admission of the first patient with EVD, a multidisciplinary team from the Centers for Disease Control and Prevention (CDC) joined the hospital's infection preventionists to implement a system of occupational safety and health controls for direct patient care, handling of clinical specimens, and managing regulated medical waste. Existing engineering and administrative controls were strengthened. The personal protective equipment (PPE) ensemble was standardized, HCP were trained on donning and doffing PPE, and a system of trained observers supervising PPE donning and doffing was implemented. Caring for patients with EVD placed substantial demands on a community hospital. The experiences of the authors and others informed national policies for the care of patients with EVD and protection of HCP, including new guidance for PPE, a rapid system for deploying CDC staff to assist hospitals ("Ebola Response Team"), and a framework for a tiered approach to hospital preparedness. The designation of regional Ebola treatment centers and the establishment of the National Ebola Training and Education Center address the need for HCP to be prepared to safely care for patients with EVD and other high-consequence emerging infectious diseases.

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The recent outbreak of Ebola virus disease (EVD) in West Africa is the largest in history (1). Ebola virus is transmitted through direct contact with an infected person's blood or bodily fluids (2). Health care personnel (HCP) caring for patients with EVD are at increased risk for infection with the virus. In West Africa, 881 HCP were infected, 513 of whom died (3). Experience treating patients with EVD in specialized biocontainment units has been reported (4–7). In 2014, a hospital in Dallas, Texas, became the first community hospital in the United States to care for a patient with EVD; 2 nurses were infected while providing care. In this article, we describe the infection prevention and control measures implemented to strengthen this hospital's capacity to safely diagnose and treat patients with EVD.

Prevention of transmission of infectious pathogens, including Ebola virus, to HCP includes 3 tiers of the "hierarchy of controls" (8–11). This standard approach to controlling workplace hazards involves using physical engineering controls that can remove or reduce exposure to a hazard; administrative controls that involve management policy and work practice training; and personal protective equipment (PPE), a supplementary method when engineering and administrative controls alone cannot provide sufficient protection (10, 11). Effective use of PPE requires comprehensive supporting programs for medical evaluation and training of employees and proper selection, fit, maintenance, and storage of equipment (12).

On 25 September 2014, a 42-year-old Liberian man presented to an emergency department in Dallas, Texas, with abdominal pain and headache (Figure 1) (13). After an evaluation described previously (13), he was treated for presumed sinusitis and discharged. On 28 September, he returned with fever, abdominal pain, and diarrhea (Figure 1). Ebola virus disease was suspected on the basis of his symptoms and his reported recent travel from Liberia, and he was placed in an isolation room (13). The patient was admitted to the medical intensive care unit (MICU) on 29 September, and EVD was confirmed by laboratory testing on 30 September. The patient's clinical course was notable for explosive diarrhea (up to 10 L/d) requiring placement of a rectal tube, development of renal failure requiring continuous venovenous hemodialysis, and a need for endotracheal intubation and mechanical ventilation for 5 days until his death on 8 October of multiorgan failure (13). On 11 October and 15 October, laboratory testing confirmed EVD in 2 MICU nurses who cared for him (14). The nurses were admitted to the MICU and later transferred to facilities with biocontainment units.

On 1 October 2014, staff from the Centers for Disease Control and Prevention (CDC) began arriving at the hospital and collaborating with the hospital's infection preventionists to provide infection control recommendations. The CDC staff included physicians and industrial hygienists with experience in occupational safety and health and infection prevention for conventional and emerging infectious agents, including Ebola virus.

See also:

Web-Only
CME quiz

Key Summary Points

Health care personnel (HCP) caring for patients with Ebola virus disease (EVD) are at increased risk for infection.

While providing care to a patient with EVD and to 2 nurses who became infected while caring for him, a U.S. community hospital strengthened a system of controls aimed at preventing disease transmission, including engineering and administrative controls and personal protective equipment (PPE).

Changes to the hospital's physical layout, procedures for handling clinical specimens and waste, job duties of HCP, and PPE ensembles required substantial investments of time, personnel, and resources.

This experience contributed to informing national policies for preparedness for EVD and has implications for other high-consequence emerging infectious diseases.

Efforts to determine how the nurses were infected were limited by the wide range of the incubation period (2 to 21 days), the lack of systematic observation, and the reliance on HCP recall to retrospectively identify instances of exposure. As such, the precise time of infection could not be determined and specific exposures that led to infection could not be identified. Thus, the approach taken to infection control was ultimately a comprehensive one, focused not on a single source of exposure but on implementing a system of controls that addressed all workplace hazards that may have contributed to the nurses' infections.

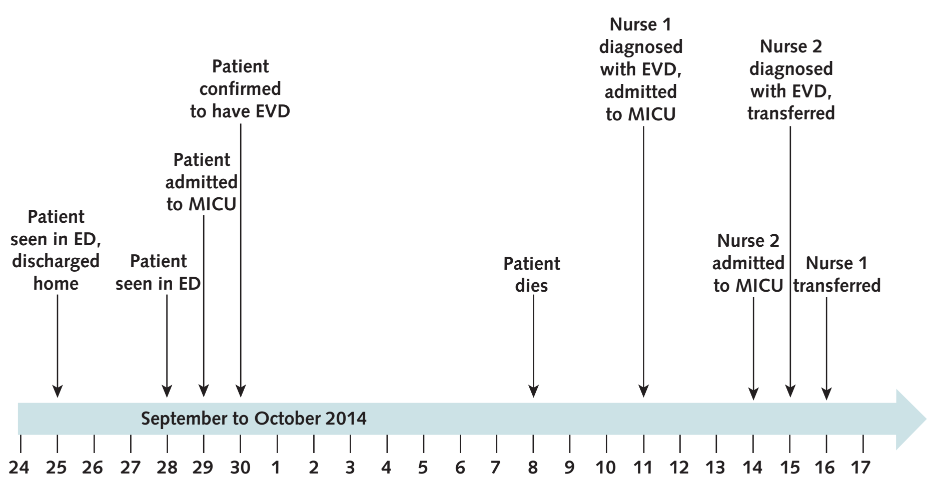
In this typical community hospital that did not have a dedicated biocontainment unit, an on-site autoclave capable of handling large volumes of waste, an on-site incinerator, or staff with pre event specialized training related to EVD, the team interviewed HCP, facility managers, laboratorians, and environmental services (EVS) managers and observed patient care activities, laboratory practices, and the management of regulated medical waste. The team developed and refined recommendations in an iterative process, building on existing controls and taking into account observations and feedback. In this article, we describe the system that was ultimately developed, emphasizing general principles, highlighting unanticipated challenges, and noting practical solutions so that our experience may benefit others faced with caring for patients with EVD or similarly challenging infectious diseases.

MICU

Engineering Controls

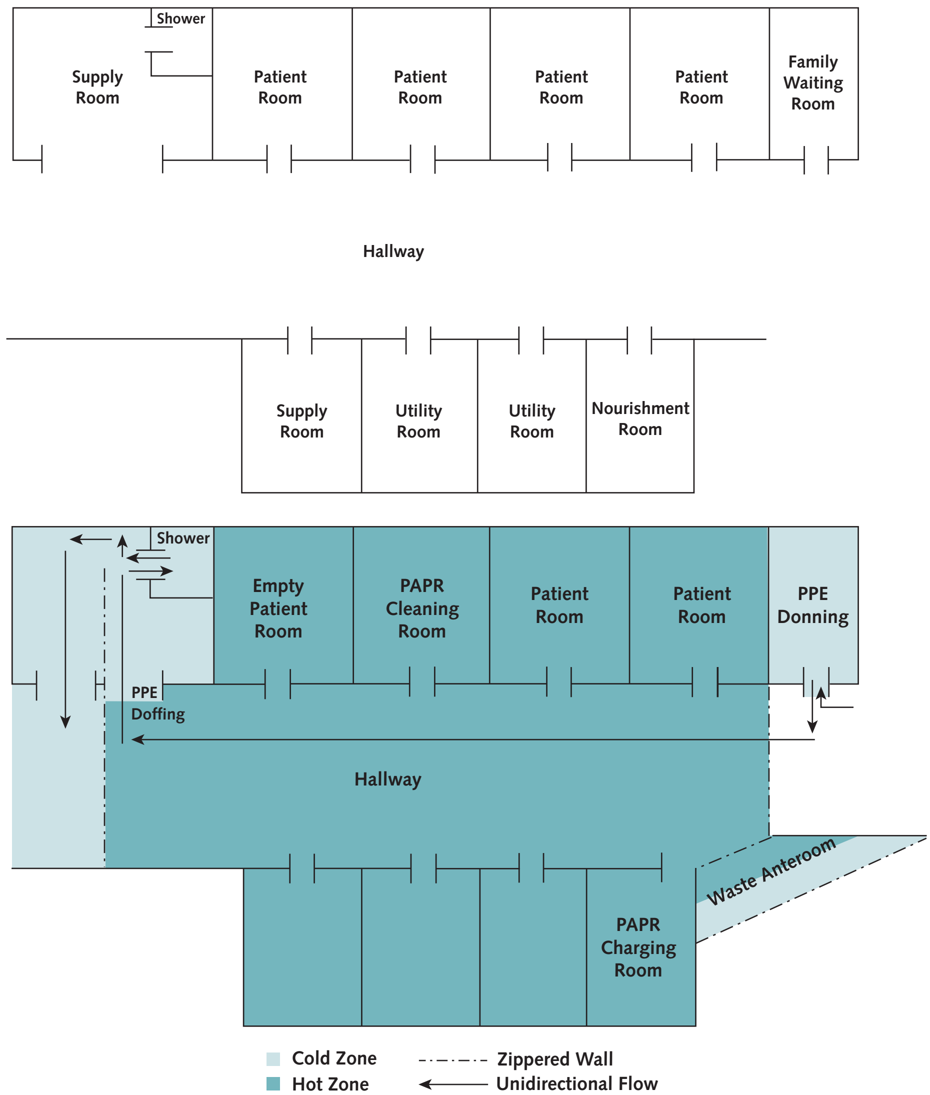
Engineering controls were implemented to change the layout of the 24-bed MICU (**Figure 2**, *top*). It was closed to patient care except for a 4-bed section demarcated by 3 tear-resistant, fire-retardant fabric walls with integrated zippers (**Figure 2**, *bottom*). The area inside the "zippered walls" was designated the "hot zone," and the area outside the zippered walls was designated the "cold zone." This approach demarcated for all HCP the area that posed a potential risk for exposure and clarified where PPE was required. A family waiting room adjacent to the hot zone was converted into the PPE donning area, and an area near the exit of the hot zone was designated as the PPE doffing area. In some biocontainment units, HCP doff PPE in a closed patient room while being observed by other HCP through a window (15). In this unit, given the staff's limited experience with specialized PPE, doffing outside the small patient room was preferable because it minimized bar-

Figure 1. Timeline of events at the first U.S. community hospital to care for patients with EVD in Dallas, Texas, September to October 2014.



ED = emergency department; EVD = Ebola virus disease; MICU = medical intensive care unit.

Figure 2. The original (*top*) and final (*bottom*) layouts of a section of the medical intensive care unit used for care of patients with Ebola virus disease at a community hospital in Dallas, Texas, September to October 2014.



The unnamed rooms in the final layout were not used. PAPR = powered air-purifying respirator; PPE = personal protective equipment.

riers to verbal communication between the HCP and the observer.

Separate entrance and exit doors for the hot zone enabled unidirectional flow and reduced the chances of "clean" HCP who were entering the hot zone being inadvertently contaminated by "dirty" HCP exiting. To enter the hot zone, HCP changed into disposable scrubs, donned PPE in the PPE donning room, and entered the hot zone through a zippered wall. To exit, HCP doffed PPE in the PPE doffing area, exited the hot zone through another zippered wall, and showered.

Administrative Controls

Early placement of an ultrasound-guided peripherally inserted central catheter minimized the need for phlebotomy and shorter-term peripheral intravenous lines. Several policies limited and tracked hot zone entry: Logs that included date and time of entry and contact information were maintained; videoconferencing capacity was established for physician–patient interactions; orders for radiology services were scrutinized to eliminate those that were not essential; and the patient care nurse assumed duties typically performed by EVS staff, such as cleaning and disinfecting the patient room and removing waste. In this way, only a limited number of staff (the patient care nurse, a second nurse to assist with patient care, and the doffing coach [described in the next section]) were routinely in the hot zone. The treating physician, consultants, and radiology technicians entered the hot zone only as needed. Others, such as the "runner" (who coordinated transfer of medication and supplies to the hot zone) and the donning coach (described in the next section), remained in the

Table 1. **Final PPE Ensembles Used for Care of Patients With Ebola Virus Disease and Handling Clinical Specimens in a Community Hospital in Dallas, Texas, in October 2014**

MICU Hot Zone	Laboratorians
External PAPR	Face mask or N95 respirator*
PAPR hood with attached shroud that covers shoulders completely	Face shield Surgical bouffant
Coveralls with integrated socks	Knee-length surgical gown with cuffed sleeves
1 pair of shoe covers 1 pair of boot covers with elastic cuff	1 pair of boot covers
2 pairs of extended-cuff nitrile gloves	2 pairs of extended-cuff nitrile gloves
Plastic apron	Disposable white laboratory coat

MICU = medical intensive care unit; PAPR = powered air-purifying respirator; PPE = personal protective equipment.
* Respiratory protection was not deemed necessary, but staff were already familiar with the respirators and elected to include them in their standard PPE ensemble.

cold zone. Training HCP in infection control procedures, including donning, use, and doffing PPE, was instituted. To reduce the frequency of PPE doffing, it was recommended that patient care nurses remain in the patient room continuously for up to 6 hours.

PPE

Personal protective equipment ensembles initially used by HCP inside the hot zone varied over time and were influenced by job duty, HCP preference, and availability of PPE items. A standard PPE ensemble was ultimately established for all HCP at all times inside the hot zone (Table 1). This fostered clarity about what PPE items were required, facilitated development of uniform donning and doffing procedures, and ensured that any HCP in the hot zone could quickly enter the patient room in an emergency.

The variable practice of augmenting the number of PPE items was discouraged. For example, instead of wearing the recommended 2 pairs of gloves, some HCP wore 3 or 4 pairs. The additional layers of PPE could make it more difficult to perform patient care duties and increase the risk for exposure during doffing (16). Because each additional PPE item worn could lead to a change in the doffing sequence, variability in the number of PPE items also precluded development of a routine order for doffing PPE.

Although Ebola virus is not believed to be transmitted by aerosol under typical conditions, hypothetical concerns about aerosol transmission to HCP during aerosol-generating procedures have been raised (17). Use of respirators is a reasonable precaution during such procedures, and respirators ultimately were recommended for any patient care activities (16). Either a disposable N95 respirator or a powered air-purifying respirator (PAPR) is appropriate (16), but we found that the more complete head and neck coverage and greater comfort of the ventilation supplied by a PAPR with a shroud were beneficial. Such advantages must be weighed against the higher cost, additional training, potentially more complex doffing procedures, greater PPE waste generation, and need for maintenance and decontamination of PAPR units.

Health care personnel applied tape to outer gloves to prevent sleeves from riding up and exposing the wrists. Silk tape tended to be highly adhesive, and its removal from the outer glove sometimes nearly caused the glove to rip. Paper tape tended to tear during doffing, and lifting the edge of a torn piece of paper tape from PPE items while wearing gloves was difficult. The ideal solution would have been to use coveralls with integrated thumb loops. Because these were not available, we elected to create thumbholes in the distal coverall sleeves, a technique that has been used by the World Health Organization (18). Any alteration of PPE should not be made lightly because alterations may negatively affect its physical integrity.

Donning and doffing multiple layers of unfamiliar PPE can be daunting, particularly for HCP involved in high-intensity patient care activities (19). We instituted a system of trained observers to act as PPE donning and doffing coaches. Available 24 hours a day, coaches read carefully worded scripts while closely observing HCP to ensure that each step was performed precisely. This eliminated the need for HCP to memorize the many donning and doffing steps and also promoted consistency in PPE donning and doffing across coaches, HCP, and shifts. Using a coached approach was particularly important for doffing, which may be complicated by fatigue, hunger, thirst, or other distractions. To minimize exposure for the doffing coaches, HCP were encouraged to doff PPE without physical assistance. However, coaches could physically assist with doffing if HCP were having difficulty. In addition, doffing coaches were responsible for addressing possible exposures (such as unintentional skin or mucous membrane contact with contaminated PPE during doffing), periodically inspecting the PPE of HCP in the hot zone, monitoring the well-being of HCP in the hot zone, disinfecting surfaces in the hot zone outside the patient rooms, and maintaining PAPRs.

Practical, simple aids were introduced to facilitate the donning and doffing processes. Mirrors were installed in donning and doffing areas for visualization. A large, square plastic security seal (typically used to secure crash carts) was attached to the small coverall zipper during donning, which helped HCP find the zipper during doffing. Grabber pick-up tools were placed in the doffing area so HCP could retrieve doffed PPE from the floor while remaining distant from potentially contaminated items.

LABORATORY SERVICES

Engineering Controls

Samples were centrifuged in a designated centrifuge with a removable, autoclavable basket. For most analyses, the blood tube was loaded onto and opened in an enclosed, automated processor line. Samples that could not be analyzed using the automated system, such as specimens for microbiological analysis, were handled under a level 2 biosafety cabinet.

Table 2. Types and Examples of Key Hazard Control Measures Implemented for Care of Patients With Ebola Virus Disease in a Community Hospital in Dallas, Texas, Between September and October 2014

Hazard Control	Description	Example
Engineering control	Eliminate, reduce, or isolate people from the hazard	Reduced MICU to a 4-bed unit Designated "hot" and "cold" zones within the MICU Created unidirectional HCP flow within the hot zone Created waste anteroom
Administrative control	Change the way people work	Limited hot zone entry Videoconferencing between providers and patients Radiology orders scrutinized to eliminate unnecessary radiographs Training of HCP in donning/doffing of standardized PPE ensembles Nurses responsible for cleaning the patient room
PPE	Protect the worker with personal protective equipment	Standardized PPE ensembles for all HCP Instituted a system of trained observers (donning/doffing coaches) Installed mirrors in the PPE donning and doffing area to ensure proper PPE wear

HCP = health care personnel; MICU = medical intensive care unit; PPE = personal protective equipment.

Administrative Controls and PPE

Samples were collected by the patient care nurse, triple-bagged with disinfection steps between bags, placed in a plastic transport canister, and passed to 2 clinical laboratory scientists in the cold zone who transported the samples to the central laboratory in a shatterproof case containing absorbent material. When possible, laboratory tests normally performed by the hospital's central laboratory were performed by the patient care nurse using a handheld whole blood analyzer at the bedside. These included basic metabolic panels and hemoglobin, hematocrit, and blood gas tests.

Analyses in the central laboratory were conducted once daily and were restricted to a limited number of preapproved tests, including comprehensive metabolic panels, complete blood counts, and malaria antigen tests and thin smears. In the central laboratory, one clinical laboratory scientist was responsible for removing the sample from the case and processing it. The other was responsible for providing clean supplies and ensuring that there were no distractions during sample processing. Equipment was decontaminated by using bleach or by decontamination processes recommended by the manufacturer.

As with HCP in the MICU, a single PPE ensemble and scripts for donning and doffing were developed for laboratorians handling and processing patient samples (**Table 1**).

WASTE MANAGEMENT

Engineering Controls

A designated waste anteroom was constructed by adding a second zippered wall separating the hot zone from adjacent nursing stations (**Figure 2**, *bottom*). Throughout their shifts, nurses in the hot zone brought double-bagged medical waste directly to the waste anteroom and placed it in 55-gallon Department of Transportation–approved category A lined cardboard drums. Environmental services staff removed the full drums from the waste anteroom and replaced them with empty drums daily. The waste anteroom allowed EVS staff to avoid an earlier practice of entering the hot zone to collect the drums.

Administrative Controls and PPE

The addition of solidifier to liquid waste (urine, vomitus, and feces) before bagging minimized the potential for the biohazard bags to leak. Nurses were asked to fill biohazard bags until they were only one-half to three-quarters full to help ensure that they would safely fit in the drums without excessive manipulation. When a biohazard bag was ready to be disposed, 100 mL of a 0.5% chlorine solution was added, the bag was hand-tied, and the outside was disinfected using hospital-grade disinfecting chlorine wipes. The bag was placed in a second biohazard bag, which was hand-tied, externally disinfected using chlorine wipes, and placed in a drum in the waste anteroom. When the drum was full, the liner was secured with a zip tie and the lid was secured with a metal band clamp. Drums were transported off-site by a contractor for incineration.

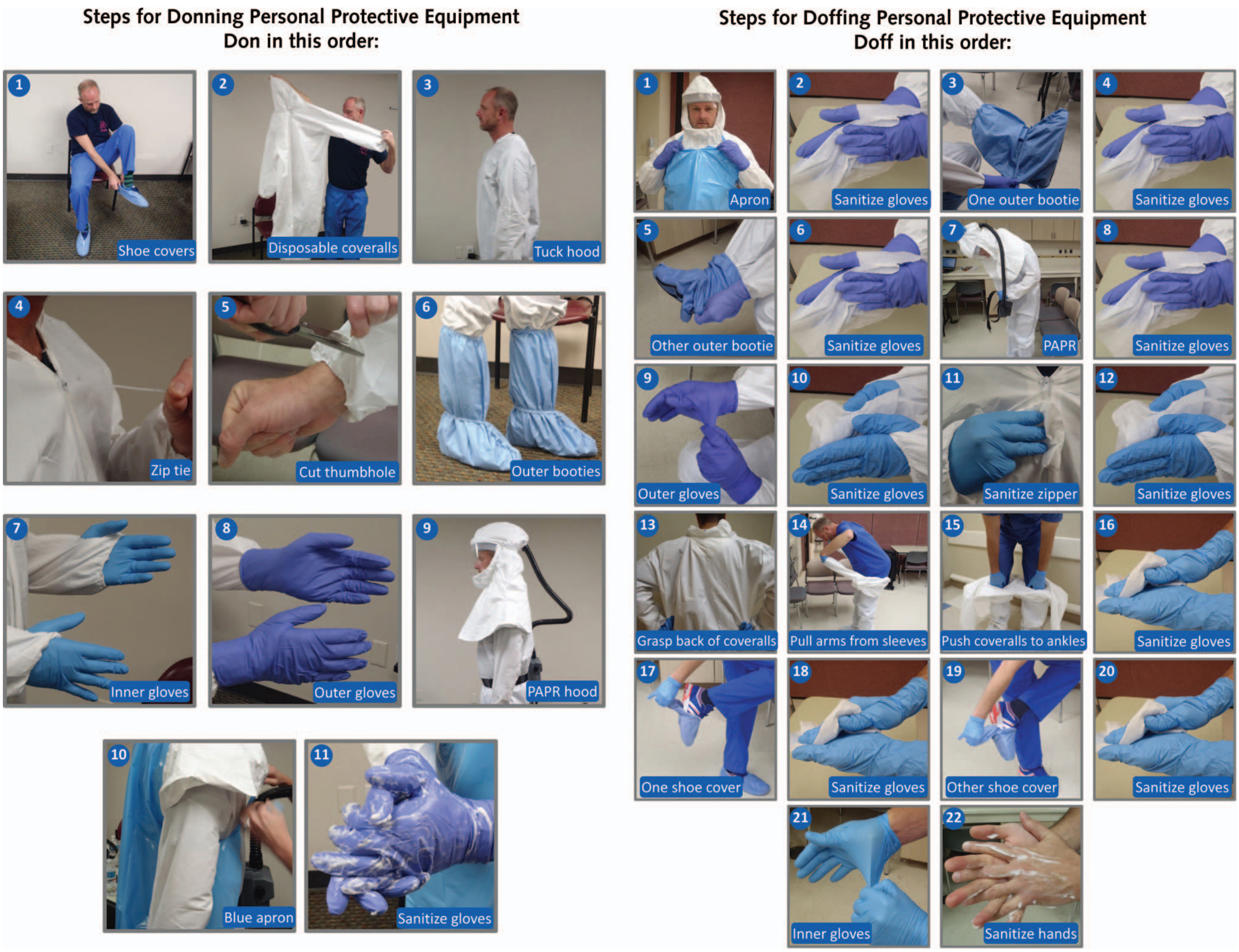
Once EVS staff no longer entered the hot zone, their recommended PPE ensemble was limited to skin protection. However, having previously worn respiratory protection in the hot zone, they chose to wear disposable N95 respirators when transporting waste.

REFLECTIONS ON AND FUTURE IMPLICATIONS OF THE LOCAL EXPERIENCE

Although PPE is often emphasized for preventing hospital transmission of EVD, its use is just one component of a comprehensive infection prevention strategy. In Dallas, multiple tiers of the occupational safety and health hierarchy of controls (engineering controls, administrative controls, and PPE) were implemented over time (**Table 2**).

Caring for patients with EVD places tremendous demands on a hospital and requires infrastructure and resources that may not be readily available in a typical community hospital. In Dallas, a single patient with EVD ultimately required at least 6 HCP per shift, closure of a large MICU to patients without EVD, purchase of extensive PPE supplies, and disposal of large amounts of category A biomedical waste. Training HCP is also time- and resource-intensive. After transfer of both nurses

Figure 3. Posters developed to facilitate donning (*left*) and doffing (*right*) of specialized personal protective equipment.



After the training courses, the posters were displayed for reference in areas of the hospital where specialized personal protective equipment would be used. PAPR = powered air-purifying respirator.

with EVD to other health care facilities, the hospital continued to evaluate HCP and community members for suspected EVD through early November 2014 (20). Given the possible need to assess and care for additional patients with EVD at this hospital, formal 4-hour training courses were organized for HCP who had not yet been trained. The hospital's education department identified those at the highest priority for training, including physicians and nurses from the emergency department, the MICU, and the labor and delivery department; EVS staff; and nurse educators. Each course included a presentation about EVD (21), a PPE demonstration, and a hands-on small group session to practice coaching and donning and doffing of PPE (Figure 3). About 160 HCP were trained over 6 days, reflecting a large investment of hospital resources.

Caring for patients with EVD also requires changes in usual HCP practices. For example, under usual conditions, nurses enter and exit a patient room many times during a shift. When caring for a patient with EVD, each of these entries and exits entails separate PPE donning and doffing episodes. Because PPE doffing is a potentially high-risk process (22), extending the time spent in the patient room may reduce the frequency of PPE doffing and thus the risk for exposure. Furthermore, HCP are asked to take on atypical responsibilities in a hazardous environment while wearing PPE that can be unfamiliar and constraining. Under these conditions, the permanent presence in the hot zone of the doffing coach, who plays the role of safety advocate, is critical.

Given the intense scrutiny the hospital faced, there was pressure to simply replicate policies and procedures developed by biocontainment units that had successfully treated patients with EVD without secondary transmission (4–7, 22–26). Although their experiences are highly informative, it is important to note that there are many potential safe approaches to the care of patients with EVD. The establishment of an integrated system of controls is more important than details that can vary from site to site, such as the brand of PAPR used; where doffing takes place; whether coaches physically assist with doffing; and whether liquid waste is treated with solidifier and bagged or placed in the toilet, disinfected, and flushed (6). A multidisciplinary team comprising infection preventionists, HCP, facilities management, and laboratorians should conduct on-site assessments to adapt the hierarchy of infection control principles (10, 27) to a particular hospital's layout, available equipment, and level of HCP training. In this way, EVD infection control measures can be appropriately tailored and effectively implemented in each unique hospital environment.

After the events described in this article, the hospital's health system assembled an expert panel to review the events related to the care of the patients with EVD and provide recommendations (28). The health system published a document in September 2015 describing the action plans it developed in response (29). Steps implemented by the time of the document's publication included ensuring rapid identification and isolation of at-risk patients, with immediate use of PPE; inclusion of basic PPE training in required annual refresher training; standardization of system-wide signage related to isolation practices, transmission precautions, and high-level PPE; and development of a system-wide interprofessional group for addressing emerging infectious disease threats. Additional plans included conducting at least 1 clinical disaster drill annually; cohorting the smallest group of HCP necessary to mitigate exposures; ensuring validation of donning and doffing competency; and expanding high-level PPE training requirements to all employees in the emergency department, the inpatient care units, the MICU, and the labor and delivery department.

In addition to these local changes, several new national recommendations and policies were established. New CDC guidance on PPE included specific recommendations for training and competency in donning and doffing, supervision of donning and doffing by a trained observer, complete skin coverage, and respirator use (16). In addition, the CDC formed an Ebola Response Team that can be mobilized anywhere in the United States within hours of strong suspicion or laboratory confirmation of EVD (30). This team provides further on-site guidance for infection control, laboratory testing, contact tracing, and HCP monitoring. An Ebola Response Team was rapidly deployed to New York City on 23 October 2014 after a physician who had volunteered in Guinea was suspected and then confirmed to have EVD (31).

The CDC and its partners introduced a 3-tiered approach to U.S. hospital preparedness for EVD, in which most hospitals are designated as "frontline health care facilities" that isolate patients with possible EVD pending transfer to a limited number of "assessment hospitals" and "treatment centers" (32). Frontline health care facilities are expected to have enough PPE for 12 to 24 hours of care, assessment hospitals are expected to have enough for up to 5 days, and treatment centers are expected to have enough for at least 7 days (32). Designation as an Ebola treatment center is a decision made by the hospital administration in discussion with state and local health authorities (33). The CDC conducted site visits to provide guidance on infection control capacity, staffing resources, PPE supplies, waste management processes, worker safety training, EVS, and laboratory set-up (32). Site visits at 81 facilities in 21 states and the District of Columbia helped 55 facilities qualify as Ebola treatment centers (34, 35).

Over the next 5 years, the U.S. Department of Health and Human Services, the Office of the Assistant Secretary for Preparedness and Response, and the CDC will provide $12 million to 3 institutions (Emory University, University of Nebraska Medical Center, and Bellevue Hospital Center) to co-lead the National Ebola Training and Education Center (36). Previously, Emory University and Nebraska Medical Center collaborated with the CDC to train more than 460 HCP from 87 health care systems on all aspects of EVD infection control and patient care. The National Ebola Training and Education Center will support further training of HCP and facilities on strategies to manage EVD and other high-consequence emerging infectious diseases.

The provision of health care is complex, and many potential contributing factors must be considered in understanding root causes of adverse events. At a community hospital caring for patients with EVD and preparing for potential additional cases, we found that a systems approach that included engineering and administrative controls and PPE was critical to improving and ensuring workplace safety and health.

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