Infection Control & Hospital Epidemiology (2022), 1–7
doi:10.1017/ice.2022.165

SHEA

Original Article

Creation and impact of containment units with high-risk zones during the coronavirus disease 2019 (COVID-19) pandemic

Natalie A. Schnell BSN, RN, RN-BC, CIC[1], Brooke Brewer MS, BSN, RN, CNML, CIC[1], Kimberly Young BSN, RN, CCRN-K[2], Turkeisha S. Brown MSN, RN, NE-BC[3], Shannon S. Carson MD[4], Loc Culp BSN, RN, CCRN[3], Cynthia Culbreth BSN, RN, CIC[1], Lauren M. DiBiase MS, CIC[1,7], William A. Fischer MD[4,6], Katherine M. Schultz MPH, BSN, RN, CIC[1], Emily E. Sickbert-Bennett PhD, MS, CIC[1,5,7], Lisa Stancill MPH[1], David J. Weber MD, MPH[1,5,6,7], Erica Wolak MHA, BSN, RN, NE-BC[3] and Lisa J. Teal BSN, RN, CIC[1]

[1]Infection Prevention, University of North Carolina at Chapel Hill Medical Center, Chapel Hill, North Carolina, [2]Performance Improvement, University of North Carolina at Chapel Hill Medical Center, Chapel Hill, North Carolina, [3]University of North Carolina at Chapel Hill Medical Center, Chapel Hill, North Carolina, [4]Division of Pulmonary and Critical Care Medicine, University of North Carolina School of Medicine, Chapel Hill, North Carolina, [5]Gillings School of Global Public Health, University of North Carolina, Chapel Hill, North Carolina, [6]Institute of Global Health and Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill, North Carolina and [7]Division of Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill, North Carolina

Abstract

Background: The rapid spread of coronavirus disease 2019 (COVID-19) required swift preparation to protect healthcare personnel (HCP) and patients, especially considering shortages of personal protective equipment (PPE). Due to the lack of a pre-existing biocontainment unit, we needed to develop a novel approach to placing patients in isolation cohorts while working with the pre-existing physical space.

Objectives: To prevent disease transmission to non–COVID-19 patients and HCP caring for COVID-19 patients, to optimize PPE usage, and to provide a comfortable and safe working environment.

Methods: An interdisciplinary workgroup developed a combination of approaches to convert existing spaces into COVID-19 containment units with high-risk zones (HRZs). We developed standard workflow and visual management in conjunction with updated staff training and workflows. The infection prevention team created PPE standard practices for ease of use, conservation, and staff safety.

Results: The interventions resulted in 1 possible case of patient-to-HCP transmission and zero cases of patient-to-patient transmission. PPE usage decreased with the HRZ model while maintaining a safe environment of care. Staff on the COVID-19 units were extremely satisfied with PPE availability (76.7%) and efforts to protect them from COVID-19 (72.7%). Moreover, 54.8% of HCP working in the COVID-19 unit agreed that PPE monitors played an essential role in staff safety.

Conclusions: The HRZ model of containment unit is an effective method to prevent the spread of COVID-19 with several benefits. It is easily implemented and scaled to accommodate census changes. Our experience suggests that other institutions do not need to modify existing physical structures to create similarly protective spaces.

(Received 16 March 2022; accepted 10 June 2022)

Before the coronavirus disease 2019 (COVID-19) pandemic, the UNC Medical Center (UNCMC) Infection Prevention team was actively working with the emergency management department and various other departments within the facility and at the state level to plan and prepare for providing medical care to patients with high-consequence pathogens. The Johns Hopkins Hospital biocontainment unit and UNCMC physician leadership research and experience with high-consequence pathogens guided our work to plan for patient placement.[1–4] When the Centers for Disease Control and Prevention (CDC) announced that COVID-19 entered pandemic status, infection preventionists attended federal training on barrier precautions and controls for highly infectious diseases.[5,6] Transmission of severe acute respiratory coronavirus virus 2 (SARS-CoV-2) to healthcare personnel (HCP) was well documented outside the United States, so swift action was needed to prepare a dedicated space for the care of COVID-19 patients.[7]

Unlike a typical biocontainment unit, we did not have dedicated clinical space designed for unidirectional movement, ample room for donning and doffing personal protective equipment (PPE), or dedicated air-handling systems designed for negative-pressure airflow or filtration of an entire patient unit. We therefore developed a plan to incorporate these principles into existing infrastructure, which included some airborne infection isolation rooms (AIIRs).

Author for correspondence: Natalie A. Schnell, E-mail: natalie.schnell@unchealth.unc.edu

Cite this article: Schnell NA, *et al.* (2022). Creation and impact of containment units with high-risk zones during the coronavirus disease 2019 (COVID-19) pandemic. *Infection Control & Hospital Epidemiology*, https://doi.org/10.1017/ice.2022.165

We then scaled these design elements up to care for large numbers of patients on multiple units.

Our goals were to prevent occupationally acquired severe acute respiratory coronavirus virus 2 (SARS-CoV-2) infections for all HCP providing patient care, to minimize PPE usage consistent with protecting HCP without compromising patient care, to improve care efficiencies, and to provide a comfortable and safe working environment.

Methods and approach

UNCMC is a large academic medical center with >950 beds and employing >11,500 HCP. Our approach was to create areas of containment designated as high-risk for COVID-19 along with areas designated as low risk. A low-risk zone (LRZ) was an area where staff adhered to universal pandemic precautions (UPP), using PPE consisting of an extended-use surgical mask and eye protection. The high-risk zone (HRZ) was an area where staff were required to wear full PPE for special airborne and contact isolation precautions at all times. Full PPE was defined as a reusable surgical gown, gloves, a controlled air-purifying respirator (CAPR) with surgical mask or an N95 respirator with eye protection. A medicine intensive care unit (ICU) was the first unit selected for COVID-19 containment based on previous plans for other high-consequence pathogens. However, realizing that a surge of patients was likely, we simultaneously prepared plans for an acute care unit (ACU). Each unit had a similar layout with some structural differences that made it impossible to obtain unidirectional personnel flow. As a result, we realized that we would need an innovative and standardized way to create safe, effective workspaces while minimizing disturbances and optimizing patient care. In addition, we needed to formulate a method for containment that could be replicated in other areas of the hospital, regardless of the layout or number of beds.

To measure HCP satisfaction with this process, an electronic survey approved by our institutional review board was sent to all staff to assess their perceptions of the medical center's efforts to protect them from acquiring COVID-19 in the fall of 2020. The survey collected occupational and primary work location data, and respondents could provide additional comments if desired.

Standard workflow and visual management

Standardizing the guidelines and workflows among the HRZs meant the functionality of the units was similar, leading to less confusion among ancillary departments, consulting providers, and floating staff. We intentionally retained nurses' stations, clean utility and equipment rooms, and automated dispensing cabinets for medications in the LRZs. Teams temporarily relocated offices, conference rooms, and call rooms to create the HRZs. Each containment unit and its corresponding nurses' station had multiple entrances (Fig. 1), including stairwells. Signage and stanchions prevented accidental HRZ entrance. If no close access to low-risk areas existed, an LRZ path 1 m wide was demarcated on the floor with tape to create a visual cue between the high- and low-risk sides of the hallway (Fig. 2). This path allowed entrance to areas that would otherwise require relocation.

Before implementing the first HRZ, we created a packet of visual management aids for each area based on input from the clinical units. These aids ensured standard and consistent visual cues throughout the hospital (Fig. 3). The units received ample signage, visual cues, and relevant containment unit workflows for implementation. Laminated signage, colored duct tape, and equipment tags with zip ties allowed the units to expand the HRZs quickly.

Staff training and preparedness

Before COVID-19, HCP had not received education on containment of high-consequence pathogens, including donning and doffing appropriate PPE for a novel respiratory virus. The infection prevention team provided comprehensive online learning modules, educational videos, and PPE guidance. To provide support for just-in-time education and to ensure high PPE compliance, we created separate donning and doffing stations for each HRZ on a unit, which were, ideally, staffed with a PPE monitor.[8] A PPE monitor is a trained, designated person who observes PPE donning and doffing. PPE monitors received education about the importance of proper PPE use and provided effective feedback. Redeployed staff or those facing closure or reduced staffing in their primary department filled PPE monitor roles. The PPE monitors promoted compliance with all steps for donning and doffing in the correct order. Doffing PPE was considered the time of highest risk for contamination, and having an observer assisting and maintaining high compliance with these steps added an increased measure of safety.[9–11]

PPE and supplies

Adjustments to nurse staffing models (ie, nurse-to-patient ratio) determined that 6 patients would be the threshold to convert an area to an HRZ with donning and doffing stations. Without an HRZ, each room entry required a new set of PPE. By caring for 6 patients inside the HRZ, HCP could care for all patients together without doffing between patients. Wearing a reusable surgical gown and a set of inner gloves allowed HCP to change only outer gloves and to use alcohol-based hand rub between patients. If a patient inside the HRZ had a concurrent multidrug-resistant infection, such as methicillin-resistant *Staphylococcus aureus*, HCP would also don a disposable isolation gown and then doff only the isolation gown and outer gloves when leaving the room.

The infection prevention team developed guidelines and standard work procedures for the movement of people, equipment, and supplies in and out of the HRZ to ensure infection control and to promote safety through consistency. Staff disinfected equipment twice upon leaving the HRZ according to the manufacturer's instructions, once inside the zone and again after exiting. Trash and soiled linen removal required new workflows in partnership with environmental services staff. If a decreasing census required conversion of portions of the HRZ back to non–COVID-19 patient beds, environmental services staff performed terminal cleaning in all rooms and enhanced cleaning in shared spaces, followed by ultraviolet room disinfection.

Predetermined patient transportation routes from the emergency department to each of the COVID-19 units were indicated by directional markers in hallways. Routes between units, procedural areas, and discharge allowed coordination between unit staff, critical care staff, and patient transport staff.

Air handling

Initial concerns about the long-distance viral transmission via aerosols led us to consider the degree of negative pressure gradient needed in rooms and hallways not designed with such capacity. AAIRs were insufficient to house all patients on the containment

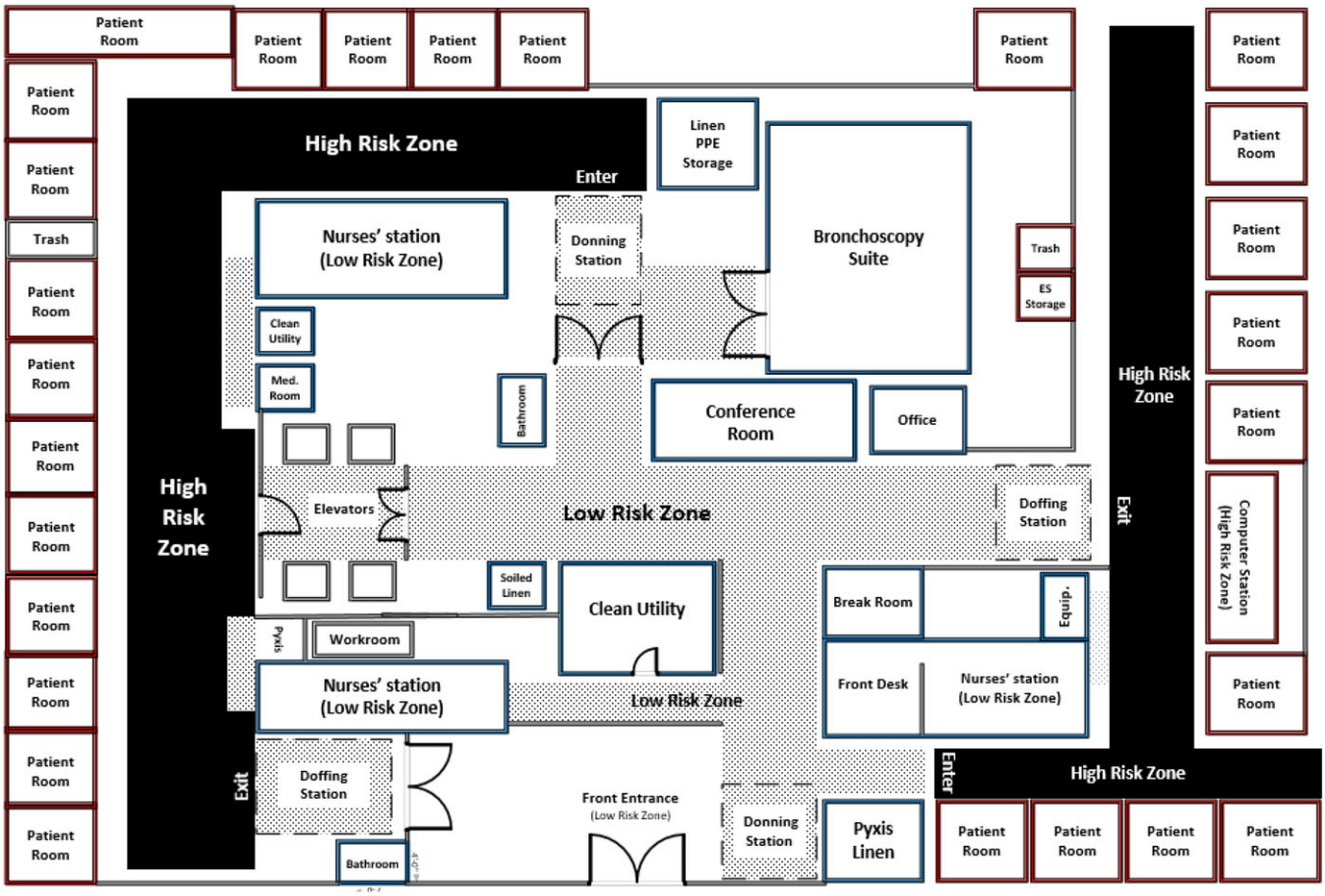

Fig. 1. Layout of acute care unit with high-risk and low-risk zones denoted. (Adapted from image courtesy of Katherine Rowe, MSN, RN, PCCN, UNC Medical Center.)

units. We considered changing the physical structure, adding air outlets into external walls of patient rooms and hallways, and/or erecting sealed barriers to contain airflow in these spaces. Ultimately, weighing the evidence supporting that SARS-CoV-2 was spread primarily over short distances via aerosols, with our aggressive timeline for preparation and considering practical limitations, we chose not to alter the physical design of our unit spaces.[12] As an alternative measure, portable high efficiency particulate air (HEPA) filter units were available for placement in patient rooms when aerosol-generating procedures (AGPs) occurred.

Clinical staffing and workflow

While in the HRZ, staff were unable to eat, drink, or use the restroom. Nursing staff on each unit rotated between the HRZ and LRZ based on HCP availability and patient acuity. Scheduled exits from the HRZ allowed for breaks at a frequency acceptable to meet these personal needs and to provide respite from wearing full PPE.

Once donned and in the HRZ, HCP did not have access to low-risk spaces, including automated dispensing cabinets, clean supplies, and nutrition areas. Therefore, at all times, it was necessary to have staff in low-risk areas facilitate obtaining and passing medications, supplies, and laboratory specimens. Retaining staff continuously within the HRZ provided immediate patient access, a benefit given the instability of many COVID-19 patients. Nurses used partners to work together between the zones, covering a group of patients and taking turns within and outside the zones.

Flexibility for fluctuations

Patient placement occurred via standardized workflow (Fig. 4). The inpatient containment units were located in the same tower of UNCMC to decrease the footprint of COVID-19 patients throughout the hospital. Due to census fluctuations, surge plans were in place to expand the high-risk portions of the units when necessary. This flexibility allowed units to maintain beds for non–COVID-19 patients simultaneously but outside the HRZ. To expand containment-unit capacity, 2 surge units, one intermediate and the other acute, were added.

Pediatric and asymptomatic obstetric patients with COVID-19 were admitted to specific units within their specialized hospitals of the Medical Center, depending on the level of care required. Fortunately, the COVID-19 census on these units never became high enough to support the resources required to maintain a containment area, but conversion plans were available. In addition, the staffing office deployed PPE monitors to the units when available.

To meet the specialized needs of psychiatric patients, we created an HRZ in a pre-existing portion of an inpatient psychiatric unit and an associated offsite inpatient psychiatric facility.[13] Patients could enter a small milieu at scheduled times. The centralized nurses' station provided an ideal space to allow staff to don PPE. After entering the contained area, staff could perform safety checks according to the protocol and doff safely at the hallway doffing station before re-entering the nurses' station. This setup also allowed staff within the nurses' station of the LRZ to see their colleagues in the HRZ.

Fig. 2. Demarcated low-risk footpath within a high-risk zone.

Fig. 3. Containment unit entrance signage.

The COVID-19 census varied over time, and the containment units needed to reduce the number of beds in the HRZ to create beds for non–COVID-19 patients. Nursing and physician leadership decided when to convert the number of COVID-19 beds with bed management, transferring patients to consolidate the HRZ if necessary. Currently, supplies from the patient rooms and hallways are used in another HRZ or discarded. Staff perform thorough disinfection of all equipment and carts. Environmental services staff terminally clean the HRZ, including the hallway and patient rooms. All rooms receive a curtain change and ultraviolet light disinfection out of an abundance of caution.

Results

Patient-to-HCP transmission findings

From April 1, 2020, to May 31, 2021, UNCMC admitted 1,512 unique COVID-19 patients within the primary COVID-19 containment units (ICU and ACU). All HCP were required to complete a daily wellness screening and to report any positive symptoms. HCP with signs or symptoms of COVID-19 were furloughed and tested for SARS-CoV-2. Occupational health staff interviewed HCP who tested positive to determine the likely source of exposure.

During this period, 17 (9%) of 189 nursing staff working on the ICU and ACU tested positive for SARS-CoV-2. Of these 17 cases, 16 were determined to be due to community or family/household exposure. The other case had an unclear source of exposure with no known exposures outside work or PPE breaches at work. Sources of exposure for 2 additional non-nursing HCP working on these units were unclear. No instances of possible patient-to-HCP transmission were noted on the surge units while functioning as containment units with HRZs.

Comparatively, 39 instances of patient-to-HCP transmission occurred in 11 units not designated as COVID-19 containment units. Causes of exposure included HCP failure to maintain adequate UPP, HCP failure to retest patients developing symptoms after admission, exposure during AGPs from patients with unknown COVID-19 status, and HCP caring for the roommate of a patient with an unknown COVID-19 status.

Patient-to-patient transmission findings

Nurses sometimes were required to care for COVID-19 and non–COVID-19 patients during rotations on the same shift, depending on staffing and unit census. The COVID-19 containment units also housed non–COVID-19 patients outside the HRZs most of the time. Importantly, there were no instances of patient-to-patient transmission between patients in high-risk and low-risk areas on the same unit.

PPE usage

Based on a block of the 6 patients needed to maintain an HRZ, we calculated the minimum number of times various HCP would need to enter a patient's room during a 12-hour shift, and we evaluated the number of doffing opportunities. The number of PPE doffing opportunities decreased by 65% when using the HRZ model (Fig. 5).

Improved HCP comfort and satisfaction

Overall, staff working exclusively on COVID-19 units were the most satisfied with UNCMC efforts to keep them safe and were similarly satisfied with PPE availability as others working in direct patient care, based on our survey. Approximately half of respondents working exclusively on COVID-19 units agreed that PPE monitors played an essential role in keeping staff safe. More respondents working equally in COVID-19 and non–COVID-19 units agreed with the importance of the PPE monitor (Fig. 6).

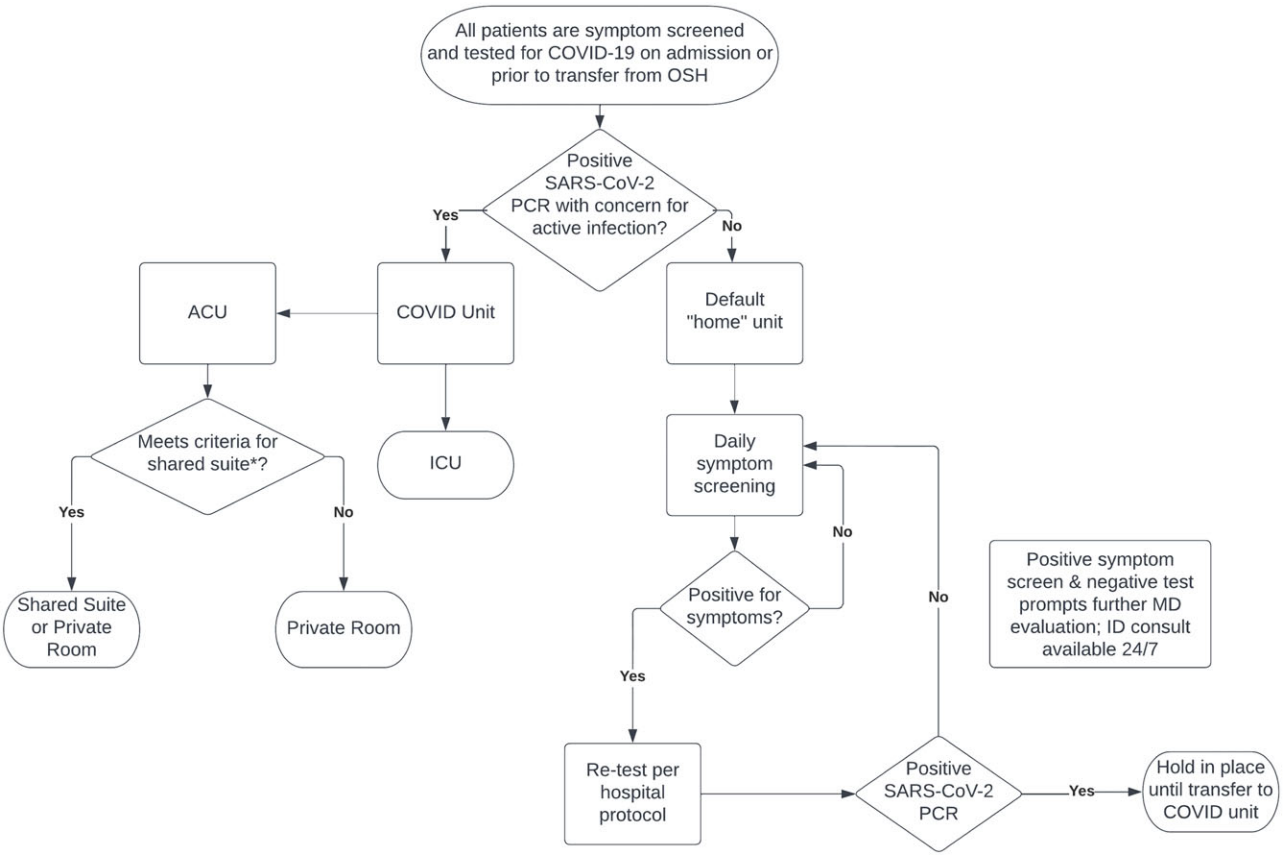

Fig. 4. Patient placement workflow at UNCMC. Note. ACU, acute care unit; ICU, intensive care unit; ID, infectious disease; OSH, outside hospital. *Contraindications for shared suite placement include concurrent infection requiring additional isolation precautions (eg, *C. difficile*), COVID-19 exposure; required aerosol-generating procedure, unable to comply with masking, other non–infection-related clinical reasons as indicated by diagnosis and/or behavior or status (eg, forensic patients, psychiatric patients, etc).

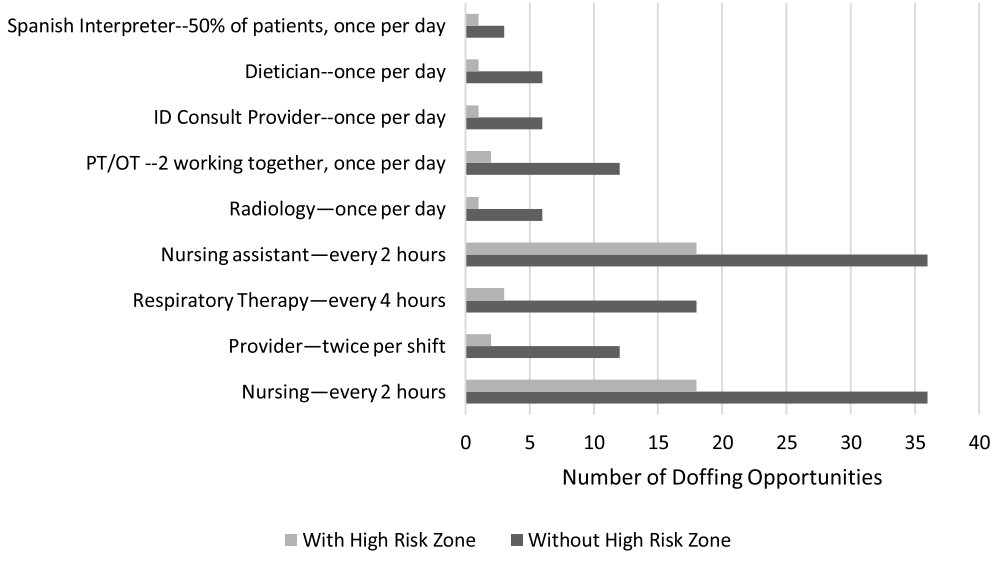

Fig. 5. Comparison of estimated minimum number of person protective equipment doffing opportunities for every 6 COVID-19 intensive care unit patients per 12-hour shift.

Discussion

Converting pre-existing patient care areas into containment units with HRZs created a safe and efficient working environment. With the HRZ method, we were able to accommodate patient surges and prepare additional units in advance. By the end of 2020, UNCMC had designated 1 intensive care unit and 1 intermediate care unit, 2 acute care units, 2 inpatient psychiatric areas, and 1 behavioral health holding area in the emergency department as containment units with HRZs at various times. Our experiences with the HRZs were positive, and staff felt safer knowing the locations of COVID-19 patients.

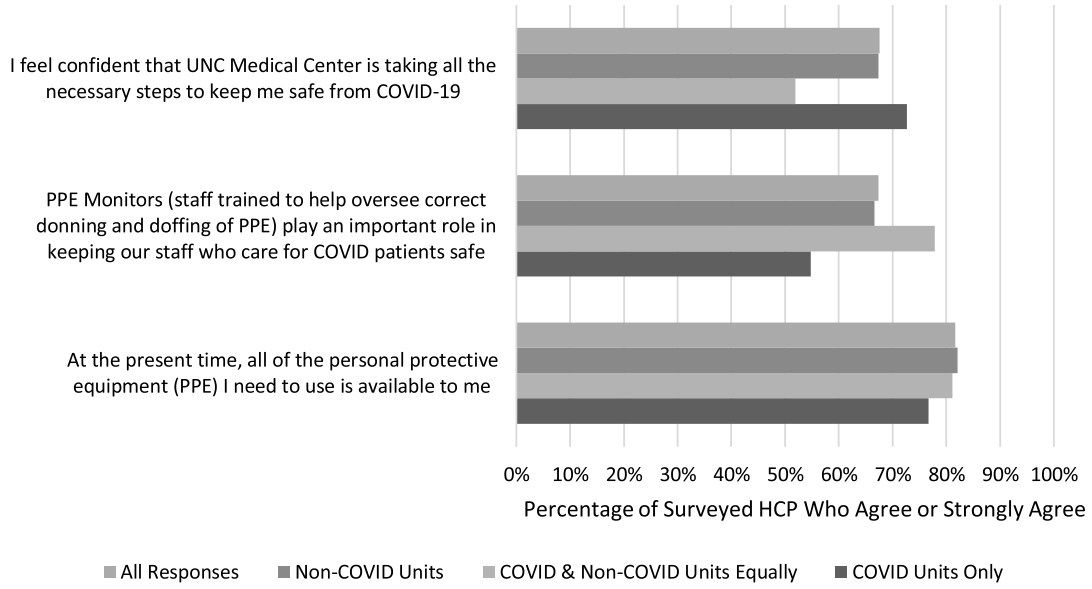

Fig. 6. Percentage of healthcare providers who agreed or strongly agreed with infection prevention strategies for COVID-19.

This research was initiated to prevent workplace transmission to HCP. Prolonged, protected exposures in the HRZs did not adversely affect the staff, who had only 3 possible cases of workplace-acquired COVID-19. Full protection is conferred with all HRZ staff wearing full PPE and adjacent staff in the LRZ wearing UPP PPE. Although there is no strong evidence of viable SARS-CoV-2 RNA in patient corridors, staff were still protected.[14,15] Over >11,000 patient days and countless HRZ entrances, AGPs, and doffing events, the use of HRZs proved to be a very efficient means for providing patient care and protecting our HCP. Although 3 SARS-CoV-2–positive HCP had an unknown exposure source, there was no way to definitively determine whether transmission occurred in the workplace from a patient source. The low rate of transmission to HCP in the HRZs suggests that it was unlikely. The lack of patient-to-patient transmission between patients in the COVID-19 containment areas and non–COVID-19 patients adjacent to the containment area also demonstrated this to be a successful model. Reducing PPE usage had the added benefit of minimizing doffing events, and therefore minimizing contamination possibilities. The HRZ method of containment unit reduced PPE usage without compromising safety and was satisfying for HCP to work in, as evidenced by survey responses. Breaks and rotating out of the HRZ provided HCP time to recharge and refocus while supporting their partner. This method was sustainable at the ideal state for more than a year, with some limitations for staffing PPE monitors for another year. When PPE monitors returned to their home departments, UNCMC created temporary positions to staff this critical role.

Survey responses from respondents working exclusively on COVID-19 units indicate high satisfaction with PPE availability. However, this satisfaction is lower than that of all responses combined. Comments from COVID-19–unit staff indicated challenges with availability or maintaining consistent supplies of smaller N95 respirators earlier in the pandemic. Staff on these units were also consistently using the PPE daily, and staff outside these units had limited opportunities for needing PPE. N95 respirators were prioritized for the containment units because our supply chain strategized to provide the safest products. Our organization uses tiered safety huddles for escalating supply safety concerns, and this was our mechanism for resolution.

COVID-19–unit staff also provided the lowest response among all groups concerning the importance of PPE monitors. Again, the timing of the survey may have influenced the responses to this question; staff on the COVID-19 units may not have felt that the PPE monitors were as crucial as they once were since the containment units had operated for at least 6 months at the time of the survey. On the other hand, the consistent coaching from PPE monitors likely built confidence and familiarity with the donning and doffing steps over time. Comparatively, respondents working equally on COVID-19 and non–COVID-19 units reported high agreement with the importance of PPE monitors. This higher proportion may be due to the respondents' comparative experiences working on non–COVID-19 units, indicative of the PPE monitors' support and overall safety.

During the Ebola outbreak, the US government invested substantial amounts of money in a small number of treatment facilities dedicated to care for high-consequence pathogen patients.[16] We show here that multidisciplinary collaboration at a facility not designated to care for patients with high-consequence pathogens could provide effective care while maintaining HCP safety. Keys to success were unit design, a modified PPE regimen with PPE monitors, and HCP buy-in. Patients with COVID-19 received priority placement in AIIRs within the HRZs. Because the existing infrastructure on each unit was maintained without any alterations to isolate airflow, it appeared that airborne transmission was not an important mechanism in the transmission of SARS-CoV-2. To protect HCP from patients with this novel respiratory virus, using a containment unit with an HRZ effectively provides source control and minimizes high-risk exposures in a population at heightened risk for acquiring COVID-19. In conclusion, the use of HRZs and standardized methods for caring for COVID-19 patients are critical strategies to keep HCP and patients safe from transmission.

Acknowledgments. We thank all healthcare personnel caring for COVID-19 patients at UNC Medical Center and all of the departments that helped support this massive undertaking.

Financial support. No financial support was provided relevant to this article.

Conflicts of interest. All authors report no conflicts of interest relevant to this article.

References

1. Garibaldi BT, Kelen GD, Brower RG, *et al.* The creation of a biocontainment unit at a tertiary care hospital. the Johns Hopkins medicine experience. *Ann Am Thorac Soc* 2016;13:600–608.
2. Fischer WA, Wohl DA. Responding to the global threat of high-consequence pathogens: protecting healthcare workers and caring for patients. *Ann Am Thorac Soc* 2016;13:584–585.
3. Weber DJ, Rutala WA, Fischer WA, Kanamori H, Sickbert-Bennett EE. Emerging infectious diseases: focus on infection control issues for novel coronaviruses (severe acute respiratory syndrome-CoV and Middle East respiratory syndrome-CoV), hemorrhagic fever viruses (Lassa and Ebola), and highly pathogenic avian influenza viruses, A(H5N1) and A(H7N9). *Am J Infect Control* 2016;44 suppl 5:e91–e100.
4. Narra R, Sobel J, Piper C, *et al.* CDC safety training course for Ebola virus disease healthcare workers. *Emerging Infect Dis* 2017;23:S217–S224.
5. Transcript for the CDC telebriefing update on COVID-19. Centers for Disease Control and Prevention website. https://www.cdc.gov/media/releases/2020/t0225-cdc-telebriefing-covid-19.html. Published 2020. Accessed March 3, 2022.
6. Center for Domestic Preparedness. *Barrier Precautions and Controls for Highly Infectious Disease Student Guide*. Anniston, AL: Department of Homeland Security; 2019.
7. Xiao J, Fang M, Chen Q, He B. SARS, MERS, and COVID-19 among healthcare workers: a narrative review. *J Infect Public Health* 2020;13:843–848.
8. Summerlin-Long S, Selimos A, Brewer B, *et al.* Building a personal protective equipment monitor team as part of a comprehensive COVID-19 prevention strategy. *Am J Infect Control* 2021;49:1443–1444.
9. Casanova LM, Rutala WA, Weber DJ, Sobsey MD. Effect of single- versus double-gloving on virus transfer to healthcare workers' skin and clothing during removal of personal protective equipment. *Am J Infect Control* 2012;40:369–374.
10. Tomas ME, Kundrapu S, Thota P, *et al.* Contamination of healthcare personnel during removal of personal protective equipment. *JAMA Intern Med* 2015;175:1904–1910.
11. Okamoto K, Rhee Y, Schoeny M, *et al.* Impact of doffing errors on healthcare worker self-contamination when caring for patients on contact precautions. *Infect Control Hosp Epidemiol* 2019;40:559–565.
12. Transmission of SARS-CoV-2: implications for infection prevention precautions. World Health Organization website. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions. Published 2020. Accessed March 2, 2022.
13. Schultz KM, Miller PB, Stancill L, *et al.* Strategies utilized to prevent and control SARS-CoV-2 transmission in two congregate, psychiatric healthcare settings during the pandemic. *Am J Infect Control* 2022;50:536–54.
14. Birgand G, Peiffer-Smadja N, Fournier S, Kerneis S, Lescure F-X, Lucet J-C. Assessment of air contamination by SARS-CoV-2 in hospital settings. *JAMA Netw Open* 2020;3:e2033232.
15. Zhang HL, Kelly BJ, David MZ, *et al.* Severe acute respiratory coronavirus virus 2 (SARS-CoV-2) surface contamination in staff common areas and impact on healthcare worker infection: prospective surveillance during the coronavirus disease 2019 (COVID-19) pandemic. *Infect Control Hosp Epidemiol* 2021. doi: 10.1017/ice.2021.468.
16. Herstein JJ, Biddinger PD, Gibbs SG, *et al.* The utility and sustainability of US Ebola treatment centers during the COVID-19 pandemic. *Infect Control Hosp Epidemiol* 2022. doi: 10.1017/ice.2022.43.