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Article

Operationalization of an Expanded Anteroom in a COVID-19 Dedicated Hospital, South Korea

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Abstract: Infection control among patients is critical for diseases like COVID-19. The concentration of patients in a few facilities burdens healthcare providers and the healthcare system. This study examined the operations of an extended anteroom in a dedicated COVID-19 hospital. It presents issues to consider in the deployment and operation of an extended anteroom through discussions by expert working groups. The subjects covered included efficient space, staffing, equipment management, and education. The process involved wearing personal protective equipment (PPE; in this case, Level D), and if necessary, wearing additional powered air purification respirators (PAPR), after moving from the preparation room to the dressing room, and when entering the hospital through the entrance passage. When leaving the hospital, personnel used a mandatory exit-only passage; in the dressing room, they undressed, and then went outside, in this order. The efficient spatial composition of the anteroom facilitated entry and exit and the separation of contaminated areas and non-contaminated areas using colors and lines. It is necessary to develop operational guidelines for hospitals that treat infectious diseases and conduct research to improve care. The study indicated the need to develop educational programs and use educational simulations to address regionally spread infectious diseases.

Keywords: COVID-19; Healthcare; Isolation hospital; Anteroom

1. Introduction

Infectious disease outbreaks have become more frequent as recent technological advances have made it easier for people to travel. Outbreaks in South Korea have included severe acute respiratory syndrome (SARS) in 2003, novel influenza A (H1N1) in 2009, and Middle East Respiratory Syndrome Coronavirus (MERS-CoV) in 2015. The spread of these infectious diseases has led to social disasters in each country [1]. On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic; and it has caused various socioeconomic problems and increased the burden on healthcare workers and providers.

As of April 23, 2020, 10,702 confirmed cases of COVID-19 and 240 COVID-19 related deaths had been reported in South Korea [2]. By contrast, as of July 2017, 186 confirmed cases of MERS-CoV and 38 MERS-CoV related deaths had been reported in South Korea [1]. These statistics demonstrate the relatively high infectiousness of SARS-CoV-2, indicating the critical need to enact effective measures to prevent transmission. Although it is difficult to estimate how many healthcare workers have been infected by SARS-CoV-2 in the absence of official reports to date, 25 out of 186 (13.4%) confirmed cases of MERS-CoV involved healthcare workers [1]. This further indicated the importance of focusing on healthcare workers and their infection prevention practices. According to a report by the WHO [3], approximately one-third of 128 lab-confirmed cases of MERS-CoV (in 14 hospitals in Jeddah between February 17 and April 26, 2014) were confirmed to involve primary infection. In contrast, over 60% of the cases (including 39 healthcare workers) involved hospital-acquired infection (HAI), suggesting the need for environmental maintenance in hospital facilities.

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Environmental maintenance for infection prevention requires technical management, administrative management, practical management, and personal protective equipment (PPE). Isolation rooms and anterooms adjacent to isolation rooms are critical for technical management [4]. After the MERS outbreak, the management of patients and contacts was emphasized in South Korea for infection prevention, and disinfection was carried out through the stringent practice of isolating patients and quarantining asymptomatic contacts [5]. Garner et al. [6] emphasized the composition of isolation rooms, negative pressure rooms, and anterooms for reducing the spread of infection in the event of an infectious disease outbreak, but experience and knowledge about the effective management of anterooms are still lacking.

An anteroom is a permanently designated place for preventing or minimizing the outflow of contaminated air when the door of an airborne infection isolation room (AIIR) opens and closes. Additionally, it is the designated space in which healthcare workers put on and remove PPE [4]. Anterooms reduce the movement of particles from the isolation room to the hallway. Moreover, areas with an anteroom are reported to be more effective in maintaining negative pressure than areas without an anteroom. However, the general perception of anterooms is that they represent space with low use or an amenity associated with additional costs at the design stage. Consequently, the provision of anterooms is low, and relevant studies or experiences are currently lacking [7]. Given this background, this paper presents a case study of operational anterooms in a dedicated infectious disease hospital (K University D Hospital) between February 21 and March 26, 2020. K University D Hospital was the first and only hospital to dedicate the whole hospital to patients with COVID-19 in South Korea. Based on this case, the present study summarizes the process of anteroom deployment and considerations when operating a dedicated infectious disease hospital with respect to an efficient floor plan, staffing, equipment management, and necessary education. This study presents useful basic data and evidence for operating anterooms during future outbreaks of infectious diseases.

2. Current operational status of local hospitals for COVID-19 patients and PPE use

Since the reporting of Patient 31 in South Korea, City “A” experienced a rapid increase in the number of confirmed cases within a few days, and it reached capacity for the existing negative pressure isolation units in the area (Figure 1). In response, “A” city designated K University D Hospital as a local hospital for patients with COVID-19, in accordance with Article 3 Paragraph 5 of the Medical Service Act. Accordingly, D Hospital transferred its regular patients to other nearby hospitals, and D Hospital was converted into an isolation facility for patients with confirmed cases of COVID-19. The entire hospital was set up as an isolation unit, and PPE donning and removal rooms were set up outside the hospital building. There are government-recommended standards and guidelines for the design of negative pressure isolation units. However, as there was no precedent for designating an entire hospital as an isolation unit and operating PPE donning and removal rooms outside the hospital building, no clear guidelines existed.

Since accepting 53 patients with confirmed cases of COVID-19 on February 22, 2020, D Hospital had been operating 465 beds as of March 26, treating an average of 313 inpatients per day and as many as 395 inpatients on a given day. Since over 300 confirmed patients began receiving treatment, the total number of healthcare workers involved became 267 people, comprising 183 nurses, 60 physicians, 11 radiologists, and 14 clinical pathologists. In addition, there were 139 other personnel responsible for disinfection and preventive measures, cleaning, and hospital maintenance, bringing the total to 406 people participating in the effort (Figure 1). PPE was put on and removed an average of 479 times per day, and as of March 26, there had been no reports of confirmed COVID-19 cases among personnel working at the hospital.

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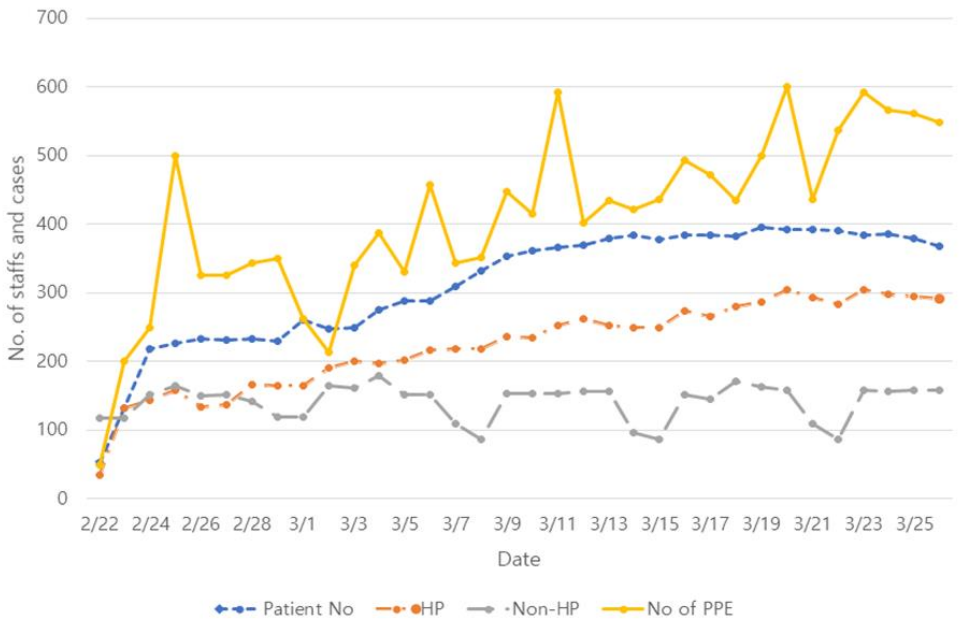

Figure 1. Current status of number of in-patient, health professional staff, non-health professional staff and usage of PPE**.**

3. Methods

This case study analyzed the operation of anterooms in a local dedicated infectious disease hospital. Recommendations for the deployment and operation of anterooms in a hospital designated for patients with COVID-19 were derived based on discussions by an expert working group. The expert working group consisted of 11 members: five nursing college professors, two hospital infection control managers with at least 10 years of clinical experience, two nursing administrators, and two nurses with at least 2 years of clinical experience. The expert working group derived improvement measures through discussions on the operation of anterooms and applied the findings directly to the field. Problems that were identified during the operation were discussed again, and additional improvement measures were explored, identified, and reapplied. By repeating this process, the anteroom deployment plan was ultimately established.

4. Results

4.1. Operational anteroom in a dedicated COVID-19 hospital

This case describes anterooms near the hospital entrance of K University D Hospital, a hospital designated for patients with COVID-19 (Figure 2). The PPE donning and doffing rooms were set up in an area in front of the hospital entrance. An area was set up for a first round of surface disinfection in the removal stage, during which powered air-purifying respirators (PAPRs) were removed and stored after receiving a second round of disinfection. Space for moving into the PAPR donning area while wearing PPE was operated separately. The floor was clearly marked so that people who were donning PPE did not cross paths with those doffing PPE. Large, clearly readable signboards were neatly posted. Professional personnel were assigned to the donning and doffing rooms to manage and educate personnel during the donning and doffing process. Additionally, personnel were assigned to manage and distribute supplies.

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Figure 2. Photograph of Anteroom.

4.2. Considerations for deployment and operation of expanded anteroom

In the expert working group discussions, the anteroom environment was created based on Korea Centers for Disease Control and Prevention "Guidelines for Operation and Management of Isolation Unit of Nationally Designated Hospitals," as revised in 2019, and the Center for Emergency Operations "COVID-19 Infection Prevention and Control Guidance (for hospital level institutions)," as revised in March 2020 [8]. An agreement was reached by revision and supplementation according to the on-site situation. Table 1 shows considerations to be taken into account when operating a local infectious disease specialty hospital. The composition of the anteroom environment was divided into the physical and the human environment. Concerning the physical environment, the PPE donning/doffing area must be set up outside the hospital since the entire area inside the hospital is designated as a contaminated zone. This area must be set up separately without easy access from the outside and managed as a caution zone.

When setting up the space for donning and doffing, separate areas must be designated as the preparation room, PPE donning room, PPE doffing room, and supply management area. The preparation room should be equipped with a personal locker room to store personal items. The PPE donning room is for donning Level D protective equipment, PAPR, and other protective equipment. The PPE doffing room must be a negative pressure area with unidirectional movement, using two doors for ingress and egress to minimize the risk of cross-infection and cross-contamination during doffing. The supply management room should be set up to store and distribute the PPE needed in the donning and doffing rooms and other supplies for environmental management.

Staffing should consist of professionals responsible for contamination and clean zones, and administrative personnel for supply management. Professional personnel are responsible for

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managing equipment needed for donning protective equipment according to the number of people in each donning area within the clean zone. These staff must also provide education on how to put on such equipment and manage the clean zone. In the contamination zone, personnel are responsible for education on how to remove protective equipment as well as providing input for the management of the environment and equipment that require disinfection. Supplies needed in the donning area include PPE, such as protective suits, goggles, gloves, mask, shoe covers, and PAPR, as well as other supplies, such as hand sanitizer, a full-length mirror for dressing, paper/silk tape, scissors, pen, paper, table, chairs, and biohazardous waste containers. Supplies needed in the doffing area include hand sanitizer, as well as tissues, apron gown, gloves, and biohazardous waste containers needed for environmental disinfection. For the hand sanitizers used in the doffing area, an automatic disperser should be used to prevent recontamination from manually pressing a lever on the hand sanitizer bottle.

Staff who enter a local infectious disease specialty hospital include medical professionals, including nurses and physicians, as well as radiologists and clinical pathologists responsible for treating and testing patients. Staff also include IT and communication managers; transportation and logistics managers; and environmental management personnel responsible for disinfection, cleaning, and facility maintenance. When entering the isolation environment, there is a difference in the level of PPE that must be worn between personnel who deal directly with patients and those who provide environmental support. These individuals have different levels of understanding about donning and doffing PPE, and they are exposed to an unfamiliar environment. Furthermore, there are a lack of opportunities for such training under normal circumstances. Therefore, consideration must be given to education that must be implemented together with environmental controls when operating an infectious disease specialty hospital.

For anteroom operation, education must cover preparation of PPE, PPE donning, PPE doffing, management after PPE is worn, coping measures in the event of unexpected exposure of PPE within the isolation unit, and environmental management of the anteroom area. Education must also include content about the selection and preparation of PPE suitable for the type of work performed by people of different occupations who must enter the hospital. The educational content should be prepared in a manual, but in addition, actual practical training on donning and doffing PPE is needed. Moreover, because the preparation, donning, and doffing rooms have a continuous flow of traffic, education led by professional personnel and video-based must be ongoing in the donning and doffing rooms.

Table 1. Consideration for Extended-Anteroom operation of Cohort hospital**.**

Category	Item		Content
Efficient Floor (Space) plan	Preparation room		- Individual rocker-room
	PPE donning room		Room or zone for wearing PPE (Level D, PAPR)
	PPE doffing room		- A negative pressure Room/zone for undressing PPE and PAPR is required which space with different door for entrance and exit - If possible, Shower facility is needed.
	Caution zone		Areas requiring attention and restricting accesses near PPE undressing zone
	Supplementary zone		Areas of material supply and management for anteroom, PPE wearing zone and undressing zone
Staffing	Health professional staff	Clean zone	- Education of wearing PPE for HCP and other workers in cohort hospital - management of PPE equipment - management of anteroom and PPE wearing room
		Isolation zone	- Education of PPE undressing - Management of undressing zone and equipment including PAPR disinfection - Management of environment of PPE undressing zone and Caution zone

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	Non-Health professional staff	Material supply	- Material and equipment management and supply for anteroom, PPE wearing zone, PPE undressing zone and caution zone - Take preventive measures against virus and disinfection for these zones.
Equipment Management	PPE and related material of PPE		- PPE (Protective clothing, goggles, gloves, mask (e.g. N95, medical mask), boot cover, PAPR equipment - Sanitizer (Manual & Automatic), full-length mirror or full wall mirror, table and chair for keeping materials, paper or silk tapes, scissors, pens, papers, and etc.
	Material for disinfection		Environmental cleansing tissues for disinfection, Dry wipe, gloves and AP gowns
Education	Preparation of PPE wearing		- Preparation for PPE according to the level of protection - Hand washing, clothes and foot wear, personal commodity storage and management
	PPE donning		- PPE check - wearing methods of PPE - handling PPE
	PPE doffing		- Process of undressing of PPE - cleansing and disinfection of PPE e.g. PAPR - management of PPE after undressing
	Personal management after PPE doffing		- moving path after undressing PPE - Personal hygiene after undressing PPE
	Handle unexpected exposure on Isolation zone		- Handle unexpected event e.g. PAPR line disconnect, PAPR low battery, tear of PPE
	Management of Cohort environment (disinfection and preventive measures)		-Periodic preventive measures and disinfection for Clean zone (anteroom, PPE donning zone) and contaminated zone

4.3. Design for operational anterooms in infectious disease dedicated hospitals

Currently, as a COVID-19 dedicated hospital, the entire hospital building has been designed as an isolation unit for patients with confirmed cases of COVID-19 (Figure 2). A modified shipping container placed near the hospital entrance is being used as the PPE doffing room. The room has two windows and an entry that is accessible 24 hours per day, in accordance with the screening center management guidelines of the Center for Emergency Operations. In this case, the hospital itself has become an isolation unit, and as a result, a section in front of the hospital must serve as an anteroom; infection control guidelines for isolation unit anterooms apply. The operation of the "expanded anteroom" is shown in Figure 3. That is, the room was set up using the concept of expanded anterooms based on entry and exit outside the hospital. First, the preparation room is used for infection education and making personal preparations for patient care. After donning the PPE in the PPE donning room, the person follows the arrows and enters the hospital through the designated entryway, wearing PAPR when necessary. When exiting, if a person has been exposed to the virus, he or she must exit through the designated exit marked in red before removing the equipment. Here, a shower may be needed, after which the person exits to the outside after removing the equipment. Additionally, Figure 3 shows the same shipping container structure being used with designated entry and exit points and with a makeshift negative pressure unit inside the doffing room to prevent any virus from escaping. All contamination zones are divided, the PPE doffing zone following exposure to the virus is marked with solid red lines to indicate a biohazard zone. Other zones, including the anteroom, are marked with dashed red lines to restrict public access and to indicate the area as a contaminated zone.

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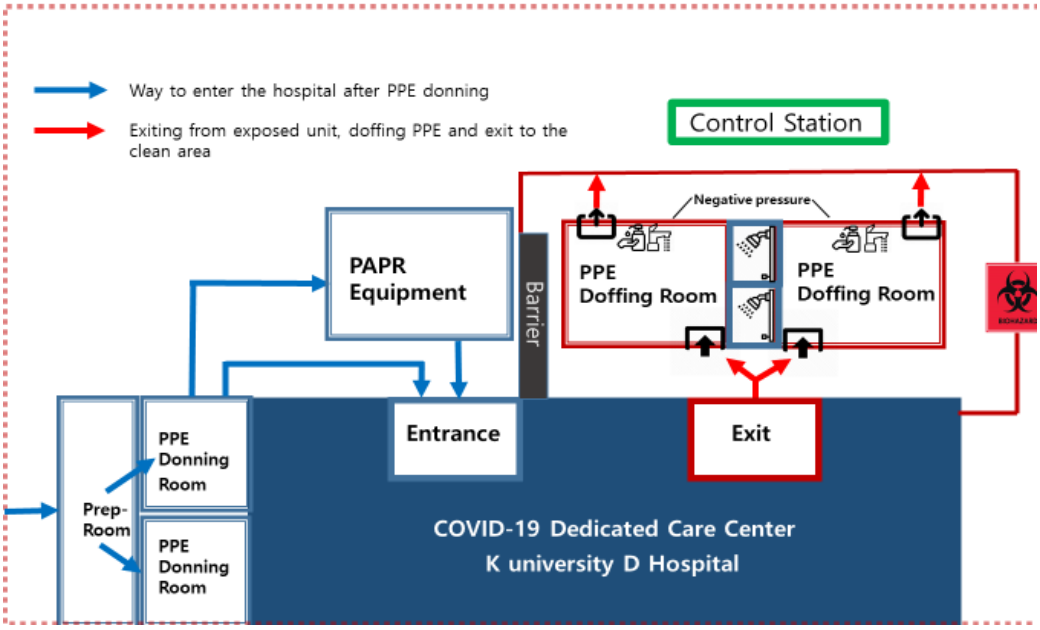

Figure 3. Designing of expanded anteroom for COVID-19 dedicated hospital.

5. Discussion

The case of K University D Hospital, which converted an entire hospital building into an isolation unit for patients with COVID-19, is unprecedented worldwide. Comparable instances may be isolation field hospitals, set up using tents and walls, which were used during the Ebola outbreak in Africa during 2013–2014 [9,10]. However, designating an entire hospital building in the center of a metropolitan city in South Korea as an isolation unit for treating patients with a respiratory infectious disease is extraordinary. The present study examined the structure and role of an expanded anteroom, which was part of a hospital that treated a large number of patients (300+), based on expert discussions and site situations.

In particular, the importance of using PPE and infection control was emphasized for treating infectious diseases. Among healthcare workers, nurses must understand the system throughout the hospital since nursing is an occupation that demands management, supervision, and education regarding the design of the environment. Furthermore, PPE donning and doffing by outside medical personnel and other environmental managers who enter the hospital is critical. Therefore, continued education and monitoring by an infection control team that includes infection control specialty nurses is especially important. It is necessary to develop educational programs according to the background of personnel and the emerging situation. In addition, it is important to develop competency for responding to mass disasters or community-acquired infection through education and training on infection control and PPE donning and removal, starting from undergraduate nursing programs [11].

The researchers observed that some personnel who had been inside the hospital removed their goggles and masks first after working for over two hours in an isolation zone, even though they had been educated on the importance of proper PPE doffing. The researchers also witnessed cases of protective suits being torn, PAPR connectors becoming lose, and goggles and masks becoming loose inside the isolation zone. Education on coping with unexpected situations and preparation of PPE must continue to ensure a safe environment for those who enter an isolation zone.

Moreover, PPE available today are susceptible to contamination during removal. Therefore, PPE should be developed to enable convenient donning and doffing to reduce the chance of infection while putting PPE on and contamination while doffing PPE. Despite healthcare workers and environmental managers donning and doffing PPE an average of 479 times per day while caring for patients, there have been no reported cases of HAI due to cross-contamination or cross-infection. It was determined that this was due to strict infection control being practiced on a individual level and that the environment was successfully managed during PPE donning and removal, the moment when contamination and infection most frequently occur.

6. Conclusions

This case study presented the composition of space needed for operating an anteroom in a hospital and associated considerations in the first hospital in South Korea that operated as a hospital for patients with COVID-19. The significance of this study was that it reported data that could be used by other regions in South Korea or other countries. In the future, the development of an operating manual for dedicated infectious disease hospitals and continued research into improvement in care is needed. Moreover, the development of educational programs for coping with community-acquired infectious diseases and the operation of simulation education centers is recommended.

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