


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

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Abstract

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 COVID-19–dedicated 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 (personal protective equipment; 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. The efficient spatial composition of the anteroom facilitated entry and exit, as well as the separation of contaminated and non-contaminated areas using colors and lines. As COVID-19 spread rapidly in the community, COVID-19–dedicated hospitals were established highly quickly. Therefore, there exists a limitation because sufficient discussion with external experts has not been made. In the future, the development of an operating manual for dedicated infectious disease hospitals and continued research into the improvement of care is needed. This study indicated the need to develop educational programs and use educational simulations, to address regionally spread infectious diseases.

Keywords

COVID-19, health care, isolation hospital, anteroom, public health

What Do We Already Know About This Topic?

- In the early stages of COVID-19, national guidelines and clinical understandings regarding the construction of extended anterooms in COVID-19–dedicated hospitals were lacking.

How Does Your Research Contribute to the Field?

- The study summarizes the process of anteroom deployment and considerations.

What Are Your Research’s Implications Toward Theory, Practice, or Policy?

- Provides considerations for the design and operation of extended anterooms in COVID-19–dedicated hospitals.

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Introduction

In May 2020, the World Health Organization (WHO) officially declared COVID-19 a global pandemic.¹ This situation has created a variety of socio-economic problems and has increased the burden on healthcare workers and healthcare providers. In South Korea, after the first confirmed case was announced in January 2020, by the end of January 2022, 76,926 confirmed cases of COVID-19 and 1386 deaths were reported.² These statistics show that SARS-CoV-2 is highly contagious, indicating the importance of taking effective measures to prevent transmission.³ Results known to date show that healthcare workers are at higher risk of contracting infection from patients or other healthcare workers, than the general population, due to potential occupational exposure.⁴ One study found that healthcare workers are 3.4 times higher⁵ at risk of contracting COVID-19 compared to the general population. This indicates the importance of focusing on healthcare workers and infection prevention practices. Proper isolation and management of COVID-19 in hospitals is essential to prevent the spread of infectious diseases in hospitals and communities, and ending the pandemic.^{6,7} This suggests that environmental maintenance of hospital facilities is necessary to prevent hospital-acquired infection.

Environmental maintenance for infection prevention requires technical, administrative, and practical management, together with personal protective equipment (PPE). Isolation rooms and anterooms adjacent to the isolation rooms are critical for technical management.⁸ The management of patients and their contacts was emphasized after the MERS outbreak in South Korea for infection prevention, and disinfection was carried out through the stringent practice of isolating patients and quarantining asymptomatic contacts.⁹ Garner et al¹⁰ 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; however, 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.⁸ Anterooms reduce the movement of particles from the isolation room to the hallway. Moreover, areas with an anteroom are reported to be highly effective in maintaining negative pressure than areas without an anteroom. However, the general perception of anterooms is that they represent a 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 of their use are currently lacking.¹¹ 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.

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 the existing negative pressure isolation units in the area reached full capacity (Figure 1). 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 rooms outside the hospital building, no clear guidelines existed.

Since accepting its first 53 patients with confirmed cases of COVID-19 on February 22, 2020, D Hospital operated 465 beds as of March 26, 2020, treating an average of 313 inpatients per day and as many as 395 inpatients on a given day. Since over 300 confirmed patients began to receive treatment, the total number of healthcare workers involved increased to 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 number of people participating in the procedure to 406 (Figure 1). PPE was worn and removed an average of 479 times per day and, as of March 26, 2020, there had been no reports of confirmed COVID-19 cases among the personnel working at the hospital.

The Process of Designing and Theoretical Considerations for Extended Anterooms

Extended anterooms operation and design process. 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 established 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 group established improvement measures through discussions on the operation of anterooms and

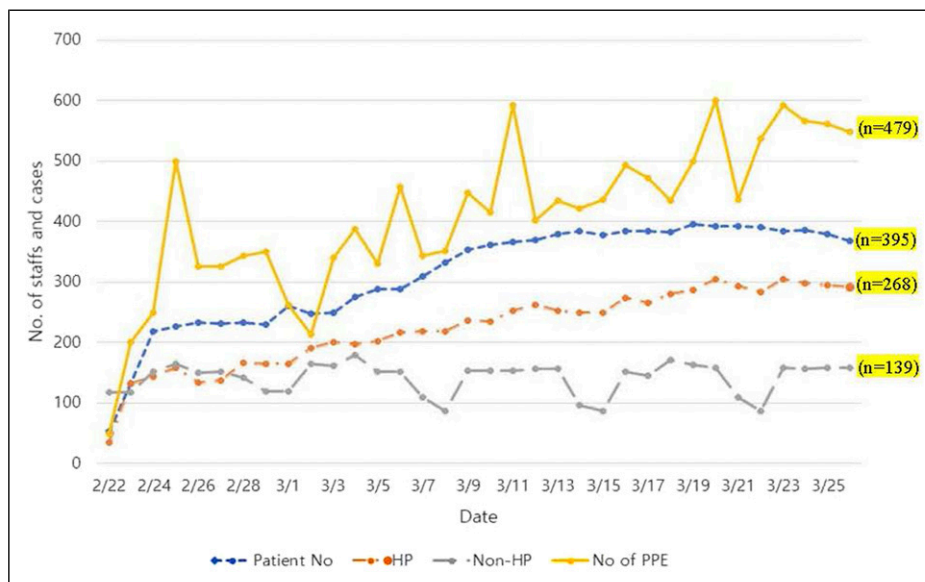


Figure 1. Number of inpatients, health professional staff, non-health professional staff, and usage of PPE.

applied the findings directly to the field. Problems that were identified during the operation were discussed repeatedly, and additional improvement measures were explored, identified, and reapplied. By repeating this process, the anteroom deployment plan was ultimately established.

Theoretical Considerations for Deployment and Operation of Expanded Anterooms

In the expert working group discussions, the anteroom environment was created based on the 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 2020.¹² An agreement was reached through revision and supplementation according to the on-site situation. Table 1 shows factors to consider when operating a local infectious disease specialty hospital. The composition of the anteroom environment was divided into the physical and human environments. Concerning the physical environment, the PPE donning or removal 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 must be managed as a caution zone.

When setting up the space for donning and removal, separate areas must be designated as the preparation room, PPE donning room, PPE removal 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 used for donning Level D protective

equipment, powered air purification respirator (PAPR), and other protective equipment. The PPE removal room must be a negative pressure area with unidirectional movement, using two doors for ingress and egress, in order to minimize the risk of cross-infection and cross-contamination during removal. The supply management room should be set up to store and distribute the PPE needed in the donning and removal rooms, as well as other supplies for environmental management.

Staffing should consist of professionals responsible for the contamination and clean zones, and administrative personnel for supply management. Professional personnel are responsible for 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 the use of equipment and the management of the clean zone. In the contamination zone, personnel are responsible for education regarding the removal of protective equipment, as well as for providing input in relation to the management of the environment and equipment that require disinfection. Supplies needed in the donning area include PPE, such as protective suits, goggles, gloves, masks, shoe covers, and PAPR, as well as other supplies, such as hand sanitizers, a full-length mirror for dressing, paper or silk tape, scissors, pens, papers, tables, chairs, and biohazardous waste containers. Supplies needed in the removal area include hand sanitizers, tissues, apron gowns, gloves, and biohazardous waste containers required for environmental disinfection. An automatic dispenser should be used for the hand sanitizers in the removal area 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, for example, nurses, physicians, radiologists, and clinical pathologists, who are responsible for

Table I. Considerations for the operation of extended anterooms in cohort hospitals.

Category	Item	Content	
Efficient floor (space) plan	Preparation room	Individual locker rooms	
	PPE donning room	Room or zone for wearing PPE (Level D, PAPR)	
	PPE removal room	A negative pressure room/zone for undressing PPE PAPR is required with different doors for entrance and exit. If possible, a shower facility is needed	
	Caution zone	Areas requiring attention and restricting access near the 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 regarding PPE removal Management of undressing zone and equipment including PAPR disinfection Management of environment of PPE undressing zone and caution zone
	Non-health professional staff	Material supply	Material and equipment management and supply for anteroom, PPE wearing zone, PPE undressing zone and caution zone preventive measures against virus and disinfection for these zones
Equipment management	PPE and related material of PPE	PPE (protective clothing, goggles, gloves, masks (eg, N95, medical mask), boot covers, PAPR equipment sanitizers (manual and automatic), full-length mirror or full wall mirror, table and chair for keeping materials, paper or silk tapes, scissors, pens, papers, etc.	
Education	Material for disinfection	Environmental cleansing tissues for disinfection, dry wipes, gloves and AP gowns	
	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 removal	Process of PPE removal Cleansing and disinfection of PPE, for example, PAPR Management of PPE after undressing	
	Personal management after PPE removal	Movement path after removal of PPE Personal hygiene after PPE removal	
	Handling unexpected exposure in isolation zone	Handling an unexpected event, for example, 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	

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 are differences in the levels 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 removing PPE, and are often exposed to an unfamiliar environment. Furthermore, there is a lack of training opportunities in this area under normal circumstances. Therefore, consideration must be given to education and environmental controls that must be implemented when operating an infectious disease specialty hospital.

Education regarding anteroom operation must cover the preparation of PPE, PPE donning, PPE removal, 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. It must also include content about the selection and preparation of PPE suitable for the type of work performed by people of different occupations in the hospital. The educational content should be prepared in a manual; however, actual practical training on donning and removal of PPE is needed. Moreover, because of the preparation required, donning and removal rooms have a continuous flow of traffic; therefore, video-based education led by professional personnel must be implemented in the donning and removal rooms.

Operational Anteroom in a COVID-19–Dedicated Hospital

As a COVID-19–dedicated hospital, the entire hospital building was designed as an isolation unit for COVID-19 patients (Figure 2). Therefore, an entire hospital building was made with the concept of an isolation unit, therefore



Figure 2. Photographs of anteroom.

conceptually, an anteroom was required. The anteroom in this study is designed to be monitored even if donning and removal were systematically trained as an expanded concept. The PPE donning and removal rooms were set up in an area in front of the hospital entrance. An area was set up for the first round of surface disinfection in the removal stage, during which PAPRs were removed and stored after receiving a second round of disinfection. A space for moving into the PAPR donning area whilst wearing PPE was operated separately. The floor was clearly marked so that people who were donning PPE did not cross paths with those removing PPE. Further, large, clearly readable signboards were neatly posted. Professional personnel were assigned to the donning and removal rooms to manage and educate personnel during the said processes. Additionally, personnel were assigned to manage and distribute supplies.

A modified shipping container placed near the hospital entrance is used as the PPE removal 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, applying the infection control guidelines for isolation unit anterooms. The operation of the “expanded anteroom” is shown in Figure 3. That is, the room that is 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 personal preparation for patient care. After donning the PPE in the PPE

donning room, an individual 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 their 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 used with designated entry and exit points, and with a makeshift negative pressure unit inside the removal room to prevent any virus from escaping. All contamination zones are divided; the PPE removal 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.

After the application of the dedicated anteroom, despite healthcare workers and environmental managers donning and removing PPE an average of 479 times per day whilst caring for patients, there have been no reported cases of hospital-acquired infection due to cross-contamination or cross-infection. It was determined that this was due to strict infection control practiced at the individual level and successful management of the environment during PPE donning and removal, especially when contamination and infection most frequently occur. However, the researchers observed that a few personnel who had been inside the hospital removed their goggles and masks first, after working for over two hours in an isolation zone, although they had been educated on the importance of proper PPE removal. The

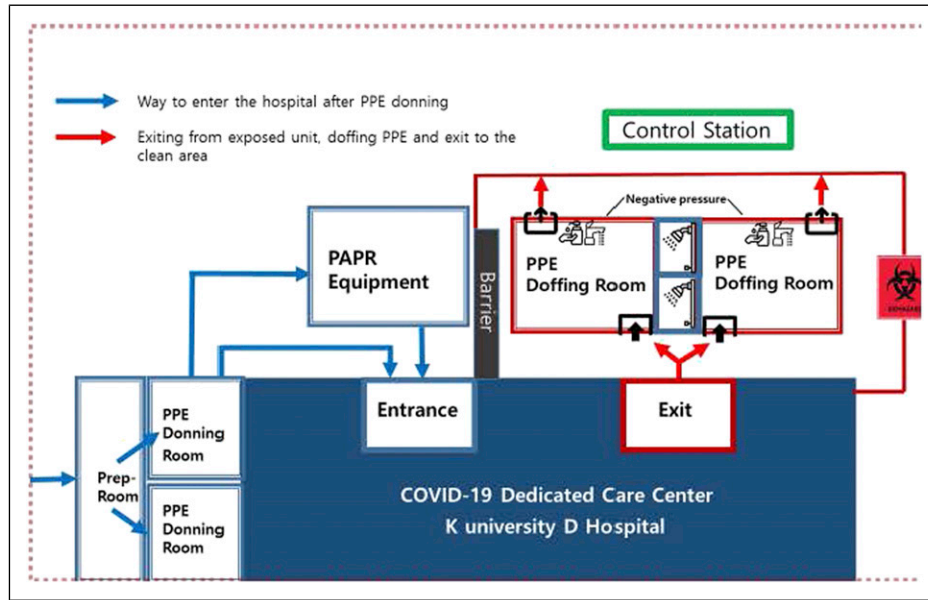


Figure 3. Design of an expanded anteroom for a COVID-19–dedicated hospital.

researchers also witnessed cases of protective suits being torn, PAPR connectors becoming loose, and goggles and masks becoming loose inside the isolation zone. Education on coping with unexpected situations and the preparation of PPE must continue to ensure a safe environment for those who enter an isolation zone.

Discussion

The COVID-19 pandemic has fueled changes in healthcare systems around the world. The challenge the healthcare system faces under the pandemic is to provide COVID-19 patients with the necessary inpatient and intensive care capacity, while simultaneously preventing healthcare workers from being exposed to the infection and hazardous environment. In order to establish a stable medical delivery system in the context of the COVID-19 pandemic, countries around the world have adopted various methods. In China, community hospitals have been transformed into designated COVID-19 hospitals.¹³ In Spain, an exhibition hall was transformed into a COVID-19 temporary hospital.¹⁴ In France, a military hospital was used to manage civilian COVID-19 patients.¹⁵ Similarly, in South Korea, as of January 2022, a total of 34 COVID-19–dedicated hospitals have been designated and operated to increase the treatment of COVID-19 patients and essential medical services.¹⁶ In the early stages of COVID-19, in the case of K University D Hospital, which converted an entire hospital building into an isolation unit for patients with COVID-19, was unprecedented worldwide. Comparable instances may include the isolation field hospitals, set up using tents and walls, and used during the Ebola outbreak in Africa during the 2013-2014 period.^{17,18} 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 situation.

In particular, the importance of using PPE and infection control was emphasized for treating infectious diseases.¹⁹ 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 removal 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.

This study is a model for the response of the medical system to the initial explosive outbreak of the pandemic. It is judged that it can be variously modified and applied to the medical community in each country for the multiple waves of COVID-19. In other words, in the case of an explosive pandemic in a short period of time, a strategy such as mobilizing the entire hospital as a COVID-19–dedicated hospital and then operating it as a usual care hospital for patient care in the region is necessary.

It is necessary to develop educational programs according to the backgrounds of personnel and newly emerging situations. 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, beginning with undergraduate nursing programs.²⁰

Moreover, the PPE available today is susceptible to contamination during removal. Therefore, PPE should be developed to enable convenient donning and removal to reduce the chance of infection.

The limitations of this study are as follows: First, due to the rapid spread of COVID-19 in Daegu, COVID-19–dedicated hospitals were established highly quickly. Therefore, there existed a few cases where an entire hospital building was operated as an infected hospital, so there was no national guideline or sufficient discussion with an external expert group. Therefore, the operationalization occurred through discussion among internal expert working groups. Second, in order to convert the hospital into a COVID-19–dedicated hospital and to design and implement the expanded anteroom, there was the difficulty of patient transfers to other hospital(s). Fortunately, however, there was no problem with existing patient care, since D Hospital was transferring patients to a new hospital with 1000 beds that was about to open in the same area. Therefore, in future research, it will be possible to re-evaluate what is needed to convert a general hospital into an isolation hospital based on a higher level of evidence through collaboration with various experts.

Conclusions

This case study presented the composition of space needed for operating an anteroom, along with associated considerations, in the first hospital in South Korea that operated as a dedicated hospital for patients with COVID-19. The findings of this study 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 the improvement of care is needed. Moreover, the development of educational programs for coping with community-acquired infectious diseases and the operation of simulation education centers are recommended.

Author Contributions

Conceptualization, KJM and SYS; methodology, KJM; investigation, HSC; resources, MSS; data curation, JYK; writing—original draft preparation, KJM and SYS; writing—review and editing, KJM; visualization, KJM; supervision, YSC; project administration, KJM and YSC. All authors have read and agreed to the published version of the manuscript.

Declaration of Conflicting Interests

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